IEC 61800-5-1

Edition 3.0 2022-08

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Adjustable speed electrical power drive systems – Part 5-1: Safety requirements – Electrical, thermal and energy

Entraînements électriques de puissance à vitesse variable – Partie 5-1: Exigences de sécurité – Électrique, thermique et énergétique

IEC 61800-5-1:2022-08(en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ADJUSTABLE SPEED ELECTRICAL POWER DRIVE SYSTEMS –

Part 5-1: Safety requirements – Electrical, thermal and energy

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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IEC 61800-5-1 has been prepared by subcommittee 22G: Adjustable speed electric power drive systems (PDS), of IEC technical committee 22: Power electronic systems and equipment. It is an International Standard.

This third edition cancels and replaces the second edition published in 2007 and Amendment 1:2016. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) harmonization with IEC 62477-1:2022;
b) harmonization with UL 61800-5-1 and CSA C22.2 No. 274, including an annex with a list of national deviation which was considered not possible to harmonize within a reasonable timeframe;
c) more detailed information about the evaluation of components according to this document and relevant safety component standards;
d) updated requirement for mechanical hazards including multiple IP ratings.

The text of this International Standard is based on the following documents:

Draft	Report on voting
22G/455/FDIS	22G/457/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

In this document, terms in *italic* are defined in Clause 3.

The reader's attention is drawn to the fact that

- Annex S and Annex T list all of the "in-some-country" clauses on differing practices of a less permanent nature relating to the subject of this document.
- Due to the rules of ISO/IEC Directives, Part 2, the term "must" instead of the term "shall" is used in Annex S and Annex T.

A list of all parts of the IEC 61800 series, published under the general title *Adjustable speed electrical power drive systems,* is available on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The "colour inside" logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this publication using a colour printer.

The contents of the corrigendum 1 (2023-09) have been included in this copy.

INTRODUCTION

0.1 General

This document contains the revision of IEC 61800-5-1:2007 and IEC 61800-5-1:2007/AMD1:2016.

Several important issues have influenced the scope and the chosen approach of the maintenance of IEC 61800-5-1:2007 in the development of this document.

The most significant changes compared to IEC 61800-5-1:2007 are the following.

a) **Structure and content is based on IEC 62477-1 considering modifications and new topics such as the following**
   - Clause 1: Scope updated to include radio emitting/transmitting *BDM/CDM/PDS*.
   - 4.1, 5.1, 6.1: "Intended use" included.
   - 4.2: Single fault/abnormal operation analysis (significantly reworked).
   - 4.3: Short-circuit and overload protection included as new subclause.
   - 4.4 and Annex A: Protection against electric shock updated according to IEC 61140:2016 and IEC 60364-4-41, including insulation coordination according to IEC 60664 (all parts) considering the following:
     - 4.4.2 – Decisive voltage classification (especially DVC As for dry, wet and salt-water wet); Table 2 and Table 3 reworked;
     - 4.4.3 – Basic protection (reworked);
     - 4.4.4 – Fault protection (reworked);
     - 4.4.5 – Enhanced protection (reworked);
     - 4.4.7 – Insulation (reworked):
       - 4.4.7.1.2 – Working voltage (new);
       - 4.4.7.1.8 – Component*s* bridging insulation (new);
       - 4.4.7.7 – *clearance* and *creepage distances* for functional insulation on PWB and component assemblies (reworked);
       - 4.4.7.8 – Solid insulation (new/reworked);
       - 4.4.7.9 – Connection of parts of solid insulation (cemented joints) (new);
     - 4.4.8/Annex H – Compatibility with RCD (reworked);
     - 4.4.10 – Access conditions for *high-voltage PDS* (new).
   - 4.5: Protection against energy hazards (new).
   - 4.6: Protection against fire and thermal hazards (new).
   - 4.7: Protection against mechanical hazards (new).
   - 4.8: *BDM/CDM/PDS* with multiple sources of supply (new).
   - 4.9: Protection against environmental stresses (new) (in alignment with IEC 61800-2).
   - 4.11: Wiring and connections updated (significantly reworked).
   - 4.12: Enclosure updated (significantly reworked).
   - 4.13 Bibliography: Evaluation of component*s* (new).
   - 4.14 Annex P: Protection against electromagnetic fields (new).
   - Clause 5: Updated with some additional/modified test requirement:
     - 5.2.2.2 – Non-accessibility test (significantly reworked);
     - 5.2.2.3 – Ingress protection test (IP rating) (significantly reworked);

- 5.2.2.4 – Enclosure integrity tests (new);
- 5.2.2.5 – Wall or ceiling mounted *BDM/CDM/PDS* test (new);
- 5.2.2.6 – Handles and manual control securement test (new);
- 5.2.2.7 – Strain relief test (new);
- 5.2.3.7 – Touch current measurement test (reworked);
- 5.2.3.9 – Limited power source (new);
- 5.2.3.11 – Protective equipotential bonding test (new);
- 5.2.3.12 – Input test (new);
- 5.2.3.13 – Thin sheet material test (new);
- 5.2.3.14 – Test procedure for determination of working voltage (new);
- 5.2.3.16 – Preconditoning of material (reworked);
- 5.2.4.4 – Protective equipotential bonding short-circuit test (new);
- 5.2.4.9 – Output overload test (new);
- 5.2.4.13.5 – Covering of openings for cooling air test (type test) (new);
- 5.2.5.6 – Cemented joints test (new);
- 5.2.7 – Hydrostatic pressure test (new);
- 5.2.8 – Electromagnetic fields (EMF) test (new).

- Clause 6: – Update with more specific marking.
  - Structure aligned with IEC 62477-1 as close as possible;
  - Table 48 simplified.
- Annex A – Additional information for protection against electric shock (reworked).
- Annex C – Symbols referred (reworked).
- Annex E – Altitude correction for *clearance*s (reworked).
- Annex F – *Clearance* and *creepage distance* determination for frequencies greater than 30 kHz (reworked).
- Annex H – Guidelines for RCD compatibility (reworked).
- Annex M – Test probes for determining access (new).
- Annex O – Guidance for determination of *clearance* and *creepage distance* (new).
- Annex P – Protection of persons against electromagnetic fields for frequencies from 0 Hz up to 300 GHz (new).
- Annex Q – Automatic disconnection of supply (new).
- Annex R – Guide 116 risk evaluation included (new).
- Bibliography – Relevant component safety standards (new).

b) Harmonization with UL 61800-5-1

Complete document is modified taken into consideration UL 61800-5-1 US National deviations. US National deviations from UL 61800-5-1 not possible to harmonize have been placed in Annex S.

c) Harmonization with CSA C22.2 No. 274

- Due to a short time frame, only some few topics have been harmonized.
- Canadian National deviations from CSA C22.2 No. 274 not possible to harmonize have been placed in Annex T.

d) Harmonization with UL 347A

- Some few relevant topics have been harmonized considering safety aspects related to *high-voltage BDM/CDM/PDS.*

Further harmonization is expected to be adopted in IEC 61800-5-1 considering the content of UL 61800-5-1, CSA C22.2 No 274 and UL 347A in future editions of IEC 61800-5-1.

0.2 Feedback from industry and national committees

The use of IEC 61800-5-1:2007 by manufacturers and test institutes since its release has identified several topics which are considered useful to implement, or topics which need further information for a better understanding of the intent of the specific requirement. These topics are also implemented in this document.

0.3 Requirement covered by other relevant parts of the IEC 61800 series

- general requirements for DC *power drive systems* are covered in IEC 61800-1;
- general requirements for AC *power drive systems* are covered in IEC 61800-2;
- EMC aspects are covered in IEC 61800-3;
- functional safety aspects are covered in IEC 61800-5-2;
- functional safety aspects for encoders are covered in IEC 61800-5-3;
- type of load duty aspects are covered in IEC TR 61800-6;
- communication profiles aspects are covered in IEC 61800-7 (all parts);
- *power interface* voltage aspects are covered in IEC TS 61800-8;
- ecodesign aspects are covered in IEC 61800-9 (all parts);

The following document is not part of the IEC 61800 series, but is used often as part of the BDM:

- active infeed converters in IEC TS 62578.

ADJUSTABLE SPEED ELECTRICAL POWER DRIVE SYSTEMS –

Part 5-1: Safety requirements – Electrical, thermal and energy

1 Scope

This part of IEC 61800 specifies requirements for adjustable speed electrical *power drive systems (PDS)* or their elements, with respect to electrical, thermal, fire, mechanical, energy and other relevant hazards. It does not cover the driven equipment except for interface requirements. It applies to adjustable speed electrical *PDS* which include the power conversion, *basic drive module (BDM)/complete drive module (CDM)* control, and a motor or motors.

Excluded are traction and electric vehicle *BDM/CDM*.

It applies to low-voltage adjustable speed electrical *PDS* intended to feed a motor or motors from a *BDM/CDM* connected to phase-to-phase voltages of up to and including 1,0 kV AC (50 Hz or 60 Hz) and up to and including 1,5 kV DC.

It also applies to high-voltage adjustable speed electrical *PDS* intended to feed a motor or motors from a *BDM/CDM* connected to phase-to-phase voltages of up to and including 35 kV AC (50 Hz or 60 Hz) and up to and including 52 kV DC.

NOTE 1 At the time of publication of this document, the technical upper voltage limit for DC motors is 2,25 kV DC.

NOTE 2 Above voltage and frequency limits reflect the scope of IEC 61800-1 and IEC 61800-2.

NOTE 3 For adjustable speed electrical *PDS* not covered by the scope of this document, applicable requirements of other standards, for example IEC 62477-1 and IEC 62477-2, can be used.

This document also applies to *PDS* which intentionally emit or receive radio waves for the purpose of radio communication.

Motors for driven equipment (see Figure 1) are covered by IEC 60034 (all parts).

NOTE 4 In some cases, safety requirements of the *PDS* (for example, protection against access to hazardous parts) can necessitate the use of special components and/or additional measures.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60034 (all parts), *Rotating electrical machines*

IEC 60034-1:2022, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60034-5:2020, *Rotating electrical machines – Part 5: Degrees of protection provided by the integral design of rotating electrical machines (IP code) – Classification*

IEC 60050-112, *International Electrotechnical Vocabulary (IEV) – Part 112: Quantities and units* (available at www.electropedia.org)

IEC 60050-113, *International Electrotechnical Vocabulary (IEV) – Part 113: Physics for electrotechnology* (available at www.electropedia.org)

IEC 60050-114, *International Electrotechnical Vocabulary (IEV) – Part 114: Electrochemistry* (available at www.electropedia.org)

IEC 60050-131, *International Electrotechnical Vocabulary (IEV) – Part 131: Circuit theory* (available at www.electropedia.org)

IEC 60050-151, *International Electrotechnical Vocabulary (IEV) – Part 151: Electrical and magnetic devices* (available at www.electropedia.org)

IEC 60050-161, *International Electrotechnical Vocabulary (IEV) – Part 161: Electromagnetic compatibility* (available at www.electropedia.org)

IEC 60050-192, *International Electrotechnical Vocabulary (IEV) – Part 192: Dependability* (available at www.electropedia.org)

IEC 60050-426, *International Electrotechnical Vocabulary (IEV) – Part 426: Explosive atmospheres* (available at www.electropedia.org)

IEC 60050-441, *International Electrotechnical Vocabulary (IEV) – Part 441: Switchgear, controlgear and fuses* (available at www.electropedia.org)

IEC 60050-442, *International Electrotechnical Vocabulary (IEV) – Part 442: Electrical accessories* (available at www.electropedia.org)

IEC 60050-551, *International Electrotechnical Vocabulary (IEV) – Part 551: Power electronics* (available at www.electropedia.org)

IEC 60050-601, *International Electrotechnical Vocabulary (IEV) – Part 601: Generation, transmission and distribution of electricity – General* (available at www.electropedia.org)

IEC 60050-826, *International Electrotechnical Vocabulary (IEV) – Part 826: Electrical installations* (available at www.electropedia.org)

IEC 60050-903, *International Electrotechnical Vocabulary (IEV) – Part 903: Risk assessment* (available at www.electropedia.org)

IEC 60068-2-1:2007, *Environmental testing – Part 2-1: Tests – Test A: Cold*

IEC 60068-2-2:2007, *Environmental testing – Part 2-2: Tests – Test B: Dry heat*

IEC 60068-2-6:2007, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-30:2005, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60068-2-52:2017, *Environmental testing – Part 2-52: Tests – Test Kb: Salt mist, cyclic (sodium chloride solution)*

IEC 60068-2-68:1994, *Environmental testing – Part 2-68: Tests – Test L: Dust and sand*

IEC 60068-2-78:2012, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60204-11:2018, *Safety of machinery – Electrical equipment of machines – Part 11: Requirements for equipment for voltages above 1 000 V AC or 1 500 V DC and not exceeding 36 kV*

IEC 60320 (all parts), *Appliance couplers for household and similar general purposes*

IEC 60364 (all parts), *Low-voltage electrical installations*

IEC 60364-4-41:2005, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*
IEC 60364-4-41:2005/AMD1:2017

IEC 60364-5-54:2011, *Low-voltage electrical installations – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements and protective conductors*
IEC 60364-5-54:2011/AMD1:2021

IEC 60417, *Graphical symbols for use on equipment* (available at https://www.graphical-symbols.info/equipment)

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*
IEC 60529:1989/AMD1:1999
IEC 60529:1989/AMD2:2013

IEC 60617, *Graphical symbols for diagrams* (available at http://std.iec.ch/iec60617)

IEC 60664-1:2020, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60664-3:2016, *Insulation coordination for equipment within low-voltage systems – Part 3: Use of coating, potting or moulding for protection against pollution*

IEC 60664-4:2005, *Insulation coordination for equipment within low-voltage systems – Part 4: Consideration of high-frequency voltage stress*

IEC 60695-2-10:2021, *Fire hazard testing – Part 2-10: Glowing/hot-wire based test methods – Glow-wire apparatus and common test procedure*

IEC 60695-2-11:2021, *Fire hazard testing – Part 2-11: Glowing/hot-wire based test methods – Glow-wire flammability test method for end-products (GWEPT)*

IEC 60695-2-13:2021, *Fire hazard testing – Part 2-13: Glowing/hot-wire based test methods – Glow-wire ignition temperature (GWIT) test method for materials*

IEC 60695-10-2:2014, *Fire hazard testing – Part 10-2: Abnormal heat – Ball pressure test method*

IEC 60695-11-10:2013, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

IEC 60695-11-20:2015, *Fire hazard testing – Part 11-20: Test flames – 500 W flame test method*

IEC 60721-3-3:1994, *Classification of environmental conditions – Part 3-3: Classification of groups of environmental parameters and their severities – Stationary use at weatherprotected locations*[1]
IEC 60721-3-3:1994/AMD1:1995
IEC 60721-3-3:1994/AMD2:1996

IEC 60721-3-4:2019, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Stationary use at non-weatherprotected locations*

IEC 60730-1:2013, *Automatic electrical controls – Part 1: General requirements*
IEC 60730-1:2013/AMD1:2015
IEC 60730-1:2013/AMD2:2020

IEC 60755:2017, *General safety requirements for residual current operated protective devices*

IEC 60799:2018, *Electrical accessories – Cord sets and interconnection cord sets*

IEC 60947-4-1:2018, *Low-voltage switchgear and controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters*

IEC 60990:2016, *Methods of measurement of touch current and protective conductor current*

IEC 61032:1997, *Protection of persons and equipment by enclosures – Probes for verification*

IEC 61084 (all parts), *Cable trunking systems and cable ducting systems for electrical installations*

IEC 61180:2016, *High-voltage test techniques for low-voltage equipment – Definitions, test and procedure requirements, test equipment*

IEC 61189-3:2007, *Test methods for electrical materials, printed boards and other interconnection structures and assemblies – Part 3: Test methods for interconnection structures (printed boards)*

IEC 61230:2008, *Live working – Portable equipment for earthing or earthing and short-circuiting*

IEC 61386 (all parts), *Conduit systems for cable management*

IEC 61558-1:2017, *Safety of power transformers, reactors, power supply units and combinations thereof – Part 1: General requirements and tests*

IEC 62109-1:2010, *Safety of power converters for use in photovoltaic power systems – Part 1: General requirements*

IEC 62271-102:2018, *High-voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches*

IEC 62477-1:2022, *Safety requirements for power electronic converter systems and equipment – Part 1: General*

[1] This publication has been withdrawn.

IEC 62477-2:2018, *Safety requirements for power electronic converter systems and equipment – Part 2: Power electronic converters from 1 000 V AC or 1 500 V DC up to 36 kV AC or 54 kV DC*

ISO 3864-1:2011, *Graphical symbols – Safety colours and safety signs – Part 1: Design principles for safety signs and safety markings*

ISO 3746:2010, *Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – Survey method using an enveloping measurement surface over a reflecting plane*

ISO 7000, *Graphical symbols for use on equipment* (available at http://www.graphical-symbols.info/equipment)

ISO 7010, G*raphical symbols – Safety colours and safety signs – Registered safety signs* (available at https://www.iso.org/obp)

ISO 9614-1:1993, *Acoustics – Determination of sound power levels of noise sources using sound intensity – Part 1: Measurement at discrete points*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-112:2010, IEC 60050-113:2011, IEC 60050-114:2014, IEC 60050-131:2002, IEC 60050-426:2020, IEC 60050-151:2001, IEC 60050-161:1990, IEC 60050-192:2015, IEC 60050-441:1984, IEC 60050-442:1998, IEC 60050-551:1998, IEC 60050-601:1985, IEC 60050-826, IEC 60050-903:2013 and IEC 60664-1:2020, and the following apply.

Table 1 provides an alphabetical cross-reference listing of terms.

Table 1 – Alphabetical list of terms

Term	Term no.	Term	Term no.	Term	Term no.
abnormal operating condition (abnormal operation)	3.1	fault protection	3.33	protective class II	3.65
accessible part	3.2	field wiring terminal	3.34	protective class III	3.66
accessory	3.3	fire enclosure	3.35	protective earthing (PE)	3.67
adjacent circuit	3.4	functional insulation	3.36	PE conductor	3.68
ambient temperature	3.5	hand-held BDM/CDM/PDS	3.37	protective impedance	3.69
basic drive module (BDM)	3.6	general-access area	3.38	reinforced insulation	3.70
basic insulation	3.7	hazardous live part	3.39	restricted-access area	3.71
basic protection	3.8	high-voltage BDM/CDM/PDS	3.40	routine test	3.72
bypass	3.9	hinged panel	3.41	sample test	3.73
BDM/CDM rated output current	3.10	installation	3.42	SELV circuit	3.74
clearance	3.11	integrated PDS	3.43	service-access area	3.75
control circuit	3.12	interlock	3.44	short-circuit backup protection	3.76
commissioning test	3.13	live part	3.45	short-circuit protective device (SCPD)	3.77
complete drive module (CDM)	3.14	low-voltage (LV)	3.46	short time withstand current (I_{cw})	3.78
component	3.15	low-voltage BDM/CDM/PDS	3.47	skilled person	3.79
conditional short-circuit current (I_{cc})	3.16	mains supply	3.48	single-fault condition	3.80
cover	3.17	minimum required prospective short-circuit current ($I_{cp,mr}$)	3.49	solid insulation	3.81
creepage distance	3.18	movable	3.50	surrounding air temperature	3.82
decisive voltage class (DVC)	3.19	non-mains supply	3.51	surroundings	3.83
door	3.20	open type	3.52	supplementary insulation	3.84
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3.1
abnormal operating condition
abnormal operation
temporary operating condition that is not a normal operating condition and is not a *single-fault condition* of the equipment itself

Note 1 to entry: An *abnormal operating condition* may be introduced by the equipment or by a person and may result in a failure of a *component*, a device or *insulation*.

[SOURCE: IEC 62368-1:2018, 3.3.7.1, modified – Note 1 to entry deleted, and Notes 2 and 3 to entry merged.]

3.2
accessible part
part or surface that can be touched by means of test probe B of IEC 61032, and if the part or surface is metal, any conductive part connected to it

Note 1 to entry: Test probe B is found in IEC 61032:1997, Figure 2. See also Figure M.2.

Note 2 to entry: Accessible non-metallic parts with conductive coatings are considered to be accessible metal parts.

[SOURCE: IEC 60335-1:2020, 3.6.3, modified – Note 1 to entry added.]

3.3
accessory
additional part, component or equipment intended to expand capabilities of the BDM/CDM/PDS, but not required for the general function of the BDM/CDM/PDS

Note 1 to entry: Typical examples are:

- external mains coils or RFI filters,
- external motor output filters,
- communication, control or input/output interface kits,
- external SPD for reduction of transient,
- additional *enclosure* parts or kits,
- additional ventilation kits,
- mechanical bonding or cable support kits, or
- additional measuring device, instrument etc.

Note 2 to entry: Expanded capabilities are considered to be electrical, mechanical, thermal or acoustic noise characteristics of the *BDM/CDM/PDS* when installed and operating as intended.

Note 3 to entry: *Accessories* and *accessory* kits might be factory or field installed.

3.4
adjacent circuit
circuit next to the circuit under consideration having a requirement for *functional insulation*, *basic insulation, double insulation* or *reinforced insulation* between them for protection

3.5
ambient temperature
average temperature of air or another medium in the vicinity of the equipment

Note 1 to entry: During the measurement of the *ambient temperature* the measuring instrument/probe should be shielded from draughts and radiant heating.

Note 2 to entry: "Equipment" includes *BDM/CDM/PDS* as well a *components*, depending on the application of the term *ambient temperature*.

Note 3 to entry: In general, the *ambient temperature* is measured in vicinity to the equipment (approx. 50 mm to 100 mm distance), shielded from heat radiation and measured at a height of approximately 50 % height of the equipment in case of passively cooled equipment, or air inlet of actively cooled equipment.

[SOURCE: IEC 60050-826:2004, 826-10-03, modified – Notes 2 and 3 to entry added.]

3.6
basic drive module
BDM
electronic power converter and related control, connected between an electric supply and a motor

Note 1 to entry: The *BDM* is capable of transmitting power from the electric supply to the motor and may be capable of transmitting power from the motor to the electric supply.

Note 2 to entry: The *BDM* controls some or all of the following aspects of power transmitted to the motor and motor output: current, frequency, voltage, speed, torque, force.

[SOURCE: IEC 61800-2:2021, 3.4]

3.7
basic insulation
insulation of *hazardous live part*s which provides *basic protection*

Note 1 to entry: This concept does not apply to *insulation* used exclusively for functional purposes.

[SOURCE: IEC 60050-195:2021, 195-06-06, modified – Words "hazardous live parts" added.]

3.8
basic protection
protection against electric shock under fault-free conditions through the use of *insulation* or distance or a combination of both

[SOURCE: IEC 60050-195:2021, 195-06-01, modified – Word "normal" replaced with "fault-free" and words "through the use of *insulation* or distance or a combination of both" added.]

3.9
bypass
circuit which, when closed, creates an alternative path for current flow in parallel with the circuit being bypassed

Note 1 to entry: The *bypass* circuit typically consists of a switch or contactor.

Note 2 to entry: The *bypass* circuit allows the original circuit to be turned off while maintaining current flow to the load.

3.10
BDM/CDM rated output current
current at the motor side of the *BDM/CDM* which can be supplied continuously without exceeding established limitations, under rated operating conditions

Note 1 to entry: For AC *BDM/CDM*, this value is expressed in RMS. For DC *BDM/CDM*, this value is expressed in average.

Note 2 to entry: This term is taken from IEC 61800-1:2021, and modified and complies with IEC 61800-2:2021.

3.11
clearance
shortest distance in air between two conductive parts

Note 1 to entry: This distance can be measured along a string stretched the shortest way between these conductive parts.

[SOURCE: IEC 60050-581:2008, 581-27-76, modified – Note to entry added.]

3.12
control circuit
circuit that carries signals directing the performance of a *BDM/CDM/PDS*, and that is not the main power circuit

3.13
commissioning test
test on a device or equipment performed on site, to prove the correctness of *installation* and operation

[SOURCE: IEC 60050-411:1996, 411-53-06, modified – Word "machine" replaced with "device".]

3.14
complete drive module
CDM
drive module consisting of, but not limited to, the *BDM* and extensions such as protection devices, transformers and auxiliaries, but excluding the motor and the sensors which are mechanically coupled to the motor shaft

[SOURCE: IEC 61800-2:2021, 3.6]

3.15
component
part of *BDM/CDM/PDS*, which cannot be physically divided into smaller parts without losing its particular function

Note 1 to entry: The term "*component"* as well as the term "sub-assembly" in this document shall be read in their context. A *component* therefore could be a single capacitor, a power supply unit, which is made of several electronic *components* as well as complete drive module inside a cabinet.

Note 2 to entry: An inverter stage (module) can also be seen as sub-assembly of a drive module.

[SOURCE: IEC 60050-151:2001, 151-11-21, modified – Words "constituent part of a device" replaced with "part of *BDM/CDM/PDS*", and notes to entry added.]

3.16
conditional short-circuit current
I_{cc}
RMS value of a *prospective short-circuit current* available from a supply source, declared by the *BDM/CDM/PDS* manufacturer under specified conditions, using a specific type of *short-circuit protective device* (SCPD) protecting the *BDM/CDM/PDS*

Note 1 to entry: The *short-circuit protective device* may form an integral part of the *BDM/CDM/PDS* or may be a separate unit.

3.17
cover
unhinged portion of an *enclosure* that closes an opening

3.18
creepage distance
shortest distance along the surface of a solid insulating material between two conductive parts

[SOURCE: IEC 60050-151:2001, 151-15-50]

3.19
decisive voltage class
DVC
classification of voltage range used to determine the protective measures against electric shock and the requirements of *insulation* between circuits

3.20
door
hinged portion of an *enclosure* that covers an opening, which is intended to be opened during routine maintenance, operations and adjustments

3.21
double insulation
insulation comprising both *basic insulation* and *supplementary insulation*

[SOURCE: IEC 60050-195:2021, 195-06-08]

3.22
direct plug-in *BDM/CDM/PDS*
BDM/CDM/PDS in which the mains plug forms an integral part of the equipment *enclosure* so that the equipment is supported by the mains socket-outlet

[SOURCE: IEC 60050-903:2014, 903-04-07, modified – Word "equipment" replaced with "*BDM/CDM/PDS*".]

3.23
DVC As
voltage classification of a circuit providing only safe to touch voltage, under normal operating conditions and *single-fault conditions* and limited overvoltages

Note 1 to entry: For limits refer to Table 2.

[SOURCE: IEC 61204-7:2016, modified – Definition reformulated.]

3.24
electrical breakdown
failure of *insulation* under electric stress when the discharge completely bridges the *insulation*, thus reducing the voltage across the *insulation* almost to zero

[SOURCE: IEC 60664-1:2020, 3.1.44, modified – Words "between the electrodes" replaced with "across the *insulation*".]

3.25
electrical insulation
insulation
electrical separation between circuits or conductive parts provided by *clearance* or *creepage distance* or *solid insulation* or combinations of them

Note 1 to entry: The meaning of *clearance* in this document is distance through air.

3.26
electrically protective screening
protective screening
separation of circuits from *hazardous live parts* by means of an interposed conductive screen, connected to the *PE conductor*, either directly or via *protective equipotential bonding*

Note 1 to entry: If the protective screening is used as a measure for enhanced protection, see 4.4.5.

3.27
electronic motor overload protection
BDM/CDM circuitry which protects a motor during overload conditions by reducing current to the motor

Note 1 to entry: The protection circuitry is usually a combination of hardware and software.

Note 2 to entry: This protection is typically achieved through an algorithm based on the I^2t of the current to the motor.

3.28
electronic power output short-circuit protection circuitry
circuitry integral to *BDM/CDM* that acts to significantly reduce current flow to the power output upon sensing a short-circuit condition

Note 1 to entry: The protection circuitry is usually a combination of hardware and software.

3.29
enclosure
housing affording the type and degree of protection suitable for the intended application

Note 1 to entry: This document provides requirements for the *enclosure* according to IEC 60529 as well as additional requirements for mechanical and environmental impact. The purpose of the additional requirements is to ensure the *enclosure's* ability to provide *basic protection* under the environmental conditions specified by the manufacturer.

[SOURCE: IEC 60050-151:2001, 151-13-08, modified – Note 1 to entry added.]

3.30
enhanced protection
protective provision having a reliability of protection not less than that provided by two independent protective provisions through the use of *insulation* or distance or a combination of both

[SOURCE: IEC 61140:2016, 3.19, modified – Word "protective provision" replaced with "protection" in the term, and words "through the use of *insulation* or distance or a combination of both" added to the definition.]

3.31
expected lifetime
design duration for which the performance characteristics are valid as specified by the manufacturer

3.32
extra-low voltage
ELV
voltage not exceeding the relevant voltage limit specified in IEC 61140:2016, Table 1

Note 1 to entry: In IEC 61140, *ELV* is defined as not exceeding 50 V AC RMS and 120 V DC. Other product committees may have defined *ELV* with different voltage levels.

Note 2 to entry: In this document, protection against electric shock is dependent on the *decisive voltage class.*

3.33
fault protection
protection against electric shock under *single-fault conditions*

Note 1 to entry: For *low-voltage installation*s, *system*s and equipment, *fault protection* in IEC 60364-4-41 generally corresponds to the formerly used "protection against indirect contact", mainly with regard to failure of *basic insulation*.

[SOURCE: IEC 60050-195:2021, 195-06-02, modified – Note to entry added.]

3.34
field wiring terminal
terminal provided for connection of external conductors to the *BDM/CDM/PDS*

Note 1 to entry: See Figure 7 and Figure 8 for examples of connection of internal and external conductors.

3.35
fire enclosure
part of the equipment intended to minimize the spread of fire or flames from within the *enclosure* to outside the *enclosure*

3.36
functional insulation
insulation between conductive parts within a circuit that is necessary for the proper function of the circuit, but which does not provide protection against electric shock

Note 1 to entry: *Functional insulation* may, however, reduce the likelihood of ignition and fire.

3.37
hand-held BDM/CDM/PDS
BDM/CDM/PDS intended to be held in the hand during normal use

[SOURCE: IEC 60050-826:2004, 826-16-05, modified – Word "equipment" replaced with *"BDM/CDM/PDS"* in the term.]

3.38
general-access area
area of the *BDM/CDM/PDS* to which both *ordinary persons* and *skilled person*s are permitted to access

Note 1 to entry: *General-access areas* do not require the use of a tool or key.

3.39
hazardous live part
live part which, under certain conditions, can give a harmful electric shock

Note 1 to entry: In this document, a hazardous live part does not meet the requirement of *DVC As* in 4.4.2.2.

[SOURCE: IEC 60050-195:2021, 195-06-05, modified – Hyphens removed from the term and note to entry replaced.]

3.40
high-voltage BDM/CDM/PDS
BDM/CDM/PDS having a *port* voltage above 1 kV AC 50 Hz or 60 Hz or above 1,5 kV DC

Note 1 to entry: "*Port*" generically applies to both input and output, and the scope of this document addresses only the range of voltages at the input power *port*.

Note 2 to entry: See IEC 61800-2:2021, Table 5.

Note 3 to entry: For *PDS* having series-connected converter sections, a sum of the series-connected phase to phase input voltages is used as the equivalent input voltage of the converter sections (see IEC 61800-2:2021, Annex A).

Note 4 to entry: In the United States of America (USA), the voltage range of this definition is considered medium voltage.

[SOURCE: IEC 61800-2:2021, 3.16, modified – Words "phase to phase" added in Note 3 to entry, "the scope of this document" replaced with "this definition" in Note 4 to entry, and Note 5 to entry deleted.]

3.41
hinged panel
portion of an *enclosure* that has hinges, but no hand-operable latching *system*, secured in the closed position by multiple bolts or other hardware requiring a tool other than a key to operate

Note 1 to entry: *Hinged panels* are not intended to be opened during normal operating conditions, routine adjustment or simple maintenance operations such as replacement of fuses.

3.42
installation
apparatus or set of devices and/or apparatuses associated in a given location to fulfil specified purposes, including all means for their satisfactory operation

Note 1 to entry: The word *installation* is also used in this document to denote the process of installing a *PDS*. In these cases, the word does not appear in italics.

[SOURCE: IEC 60050-151:2001, 151-11-26, modified – Note to entry added.]

3.43
integrated PDS
PDS where motor and *BDM/CDM* are mechanically integrated into a single unit

[SOURCE: IEC 61800-2:2021, 3.28, modified – Word "combined" replaced with "mechanically integrated".]

3.44
interlock
device(s) that prevent operation of some other device with which it is directly associated under specific conditions

Note 1 to entry: *Interlock*s may be electrical, mechanical, or a combination of both.

3.45
live part
conductive part intended to be energized under normal operating conditions, including the neutral conductor and mid-point conductor, but excluding the PEN conductor, PEM conductor and PEL conductor

Note 1 to entry: This concept does not necessarily imply a risk of electric shock.

Note 2 to entry: By convention, the PE conductor is not a live part.

[SOURCE: IEC 60050-195:2021, 195-02-19, modified – Notes to entry added.]

3.46
low-voltage
LV
set of voltage levels used for the distribution of electricity and whose upper limit is generally accepted to be 1 000 V AC or 1 500 V DC

[SOURCE: IEC 60050-601:1985, 601-01-26, modified – Words "or 1 500 V DC" added.]

3.47
low-voltage BDM/CDM/PDS
BDM/CDM/PDS having a *port* voltage less than or equal to 1 kV AC (50 Hz or 60 Hz) or 1,5 kV DC

Note 1 to entry: For *PDS* having series-connected converter sections, a sum of the series-connected input voltages is used as the equivalent input voltage of the converter sections (see IEC 61800-2:2021, Annex A).

[SOURCE: IEC 61800-2:2021, 3.30, modified – Note 2 to entry deleted.]

3.48
mains supply
low-voltage or *high-voltage* power distribution *system* for supplying power to a *BDM/CDM/PDS*

3.49
minimum required prospective short-circuit current
$I_{\mathrm{cp,mr}}$
RMS value of a minimum *prospective short-circuit current*, which shall be available from the source to ensure operation of the specific type of *short-circuit protective device*

[SOURCE: IEC 62477-1:2022, 3.38]

3.50
movable
<*BDM*/*CDM*/*PDS*> equipment that is either:

– 18 kg or less in mass and not fixed in place, or
– provided with wheels, casters, or other means to facilitate movement by an *ordinary person* as required to perform its intended use

[SOURCE: IEC 60050-903:2014, 903-04-06, modified – Word "limited" replaced with "18 kg or less", and Note to entry deleted.]

3.51
non-mains supply
electrical source that is not connected directly to the *mains supply*

Note 1 to entry: Examples of *non-mains supplies* are those which are isolated from the *mains supply* by a transformer or supplied by a battery, generator, solar arrays, wind generator, tidal systems, wave, fuel cell or similar sources not directly connected to the AC or DC power distribution system.

3.52
open type
<*BDM/CDM*> intended to be incorporated within an *enclosure* or *restricted-access area* that will provide protection against hazards

Note 1 to entry: Hazards are defined in 4.2.

3.53
ordinary person
person who is not a *skilled person*

EXAMPLE An operator, any person who may have access to the equipment or any person who may be in the vicinity of the equipment, when such equipment is not installed in a *restricted-access area.*

[SOURCE: IEC 60050-826:2004, 826-18-03, modified – Words "nor an instructed person" deleted, and example added.]

3.54
output short-circuit current
available current that flows at the output power *port* of the *BDM/CDM* when a short-circuit is applied by a conductor of negligible impedance

3.55
overcurrent
current in excess of the rated current

Note 1 to entry: In this document, the term *overcurrent* covers both short-circuit and overload.

3.56
PELV circuit
electric *system* in which the voltage cannot exceed the value of *extra-low voltage*:

– under normal operating conditions; and
– under *single-fault conditions*, except earth faults in other electric circuits

Note 1 to entry: *PELV* is the abbreviation for protective *extra-low voltage*.

[SOURCE: IEC 60050-826:2004, 826-12-32, modified – Word "system" replaced with "circuit" in the term, and word "operating" added to the first dash.]

3.57
permanently connected equipment
equipment that can only be connected to or disconnected from the electric power *system* by the use of a tool

[SOURCE: IEC 60050-151:2014, 151-11-29]

3.58
pluggable equipment type A
equipment that is intended for connection to the *mains supply* or *non-mains supply* via a non-industrial plug and socket-outlet or via a non-industrial appliance coupler, or both

Note 1 to entry: For non-industrial plug and socket-outlets, see IEC TR 60083 or a national equivalent. For non-industrial appliance couplers, see IEC 60320-1.

[SOURCE: IEC 60050-903:2014, 903-04-08, modified – Word "*mains*" replaced with "*mains supply or non-mains supply*".]

3.59
pluggable equipment type B
equipment that is intended for connection to the *mains supply* or *non-mains supply* via an industrial plug and socket-outlet or via an industrial appliance coupler, or both

Note 1 to entry: For industrial plug and socket-outlets, see IEC 60309-1 or a national equivalent. For non-industrial appliance couplers, see IEC 60320-1.

[SOURCE: IEC 60050-903:2014, 903-04-09, modified – Word "*mains*" replaced with "*mains supply or non-mains supply*".]

3.60
port
access to a device or network where electromagnetic energy or signals may be supplied or received or where the device or network variables may be observed or measured

Note 1 to entry: In this document, "input", "output", "power" and "control" are indicated to define usage.

Note 2 to entry: For the evaluation of safety, ports also cover power interfaces as defined in IEC 61800-1:2021, IEC 61800-2:2021 and IEC 61800-3:2017.

[SOURCE: IEC 60050-131:2002, 131-12-60, modified – Note replaced with Note 1 to entry and Note 2 to entry.]

3.61
power drive system
PDS
system consisting of one or more *complete drive module*(s) (*CDM*) and a motor or motors

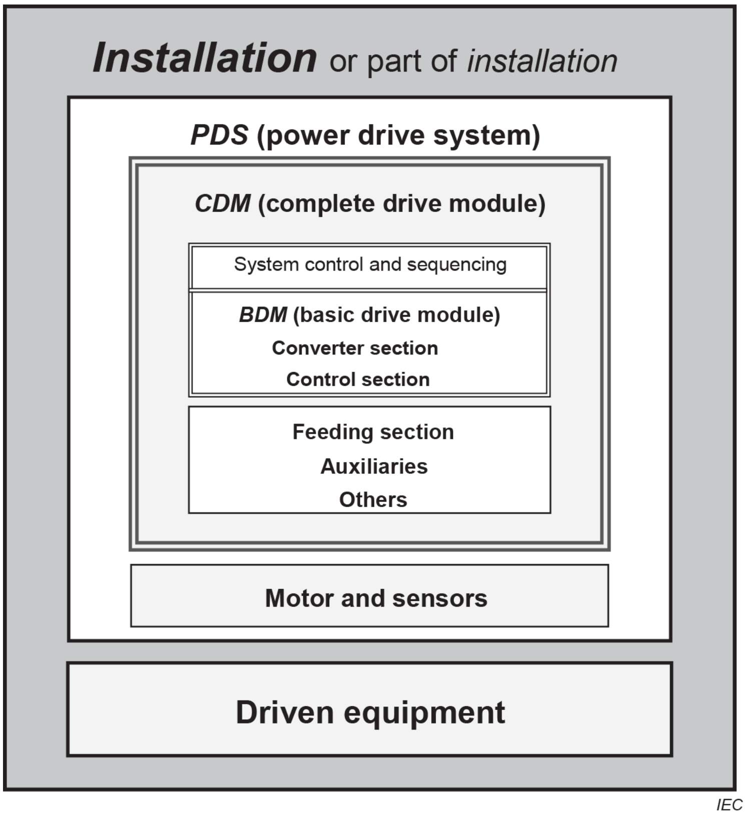


Figure 1 – *PDS* hardware configuration within an *installation*

Note 1 to entry: See Figure 1. For more detailed information, see IEC 61800-2:2021, Figure 1.

Note 2 to entry: Any sensors which are mechanically coupled to the motor shaft are also part of the *PDS*; however, the driven equipment is not included.

[SOURCE: IEC 61800-2:2021, 3.52, modified – Note 1 to entry added.]

3.62
prospective short-circuit current
I_{cp}
RMS value of the symmetrical current which would flow if the supply conductors to the circuit are short-circuited by a conductor of negligible impedance located as near as practicable to the supply terminals of the *BDM/CDM/PDS*

[SOURCE: IEC 61439-1:2020, 3.8.7, modified – Word "current" replaced with "RMS value of the symmetrical current", and "assembly" with "*BDM/CDM/PDS*".]

3.63
protective equipotential bonding
provision of electric connections between conductive parts, intended to minimize any difference in potential between those parts, for purposes of safety

EXAMPLE Protection against electric shock.

3.64
protective class I
equipment in which protection against electric shock does not rely on *basic protection* only, but which includes an additional safety precaution in such a way that means are provided for the connection of conductive *accessible parts* to the *PE conductor* in the fixed wiring of the *installation*, in such a way that conductive *accessible parts* cannot become live in the event of a failure of the *basic insulation*

Note 1 to entry: *Protective class I* is defined in IEC 61140:2016, 7.3.

3.65
protective class II
equipment in which protection against electric shock does not rely on *basic protection* only, but in which additional safety precautions such as *supplementary insulation* or *reinforced insulation* are provided, there being no provision for *protective earthing* or reliance upon *installation* conditions

Note 1 to entry: *Protective class II* is defined in IEC 61140:2016, 7.4.

3.66
protective class III
equipment in which protection against electric shock relies on supply at *DVC As* (or *DVC B* under certain conditions) and in which voltages higher than those of *DVC As* (*DVC B*) are not generated and there is no provision for *protective earthing*

Note 1 to entry: *Protective class III* is defined in IEC 61140:2016, 7.5.

Note 2 to entry: Other standards define *protective class III* as supplied by *ELV*.

3.67
protective earthing
PE
earthing of a point in a *system*, or equipment, for protection against electric shock in case of a fault

3.68
PE conductor
conductor in the *installation* wiring or in the power supply cord, connecting a main protective earthing terminal in the equipment to an earthing point in the *installation* for safety purposes

Note 1 to entry: In the USA and Canada, the term "ground" is used instead of "earth".

3.69
protective impedance
impedance connected between *hazardous live parts* and conductive *accessible parts*, of such value that the current, under normal operating conditions and under *single-fault conditions*, is limited to a safe value, and which is constructed so that its ability is maintained throughout the life of the equipment

[SOURCE: IEC 60050-442:1998, 442-04-24, modified – Definition reformulated.]

3.70
reinforced insulation
insulation of *hazardous live parts* which provides a degree of protection against electric shock equivalent to *double insulation*

[SOURCE: IEC 60050-826:2004, 826-12-17, modified – Note to entry deleted.]

3.71
restricted-access area
enclosed electrical area not intended for service, maintenance or commissioning while the *BDM/CDM/PDS* is energized and to which only *skilled person*s are permitted to access

Note 1 to entry: *Restricted-access areas* require the use of a tool or key to get access.

3.72
routine test
conformity test made on each individual item during or after manufacture

[SOURCE: IEC 60050-151:2001, 151-16-17]

3.73
sample test
test on a number of devices taken at random from a batch

[SOURCE: IEC 61800-2:2021, 3.85]

3.74
SELV circuit
electric *system* in which the voltage cannot exceed the value of *extra-low voltage*:

– under normal conditions; and
– under *single-fault conditions*, including earth faults in other electric circuits

Note 1 to entry: *SELV* is the abbreviation for safety *extra-low voltage*.

[SOURCE: IEC 60050-826:2004, 826-12-31, modified – Word "system" replaced with "circuit" in the term.]

3.75
service-access area
enclosed electrical area intended for service, maintenance and commissioning while the *BDM/CDM/PDS* is energized and to which only *skilled person*s have permitted to access

Note 1 to entry: *Service-access areas* require the use of a tool or key to get access.

Note 2 to entry: *Service-access area* can be a place within a building or a space within an *enclosure*.

3.76
short-circuit backup protection
protection that is intended to operate when other protective measures within a *system* or equipment fail to clear a fault

[SOURCE: IEC 62477-1:2022, 3.67]

3.77
short-circuit protective device
SCPD
device intended to protect a circuit or parts of a circuit against short-circuit currents by interrupting them

Note 1 to entry: A *short-circuit protective device* is suitable for protection against short-circuit only, not for protection against overload. An *overcurrent* protective device may also incorporate the function of a *SCPD*.

[SOURCE: IEC 61439-1:2020, 3.1.11, modified – Note to entry added.]

3.78
short time withstand current
I_{cw}
RMS value of short time current, declared by the *BDM*/*CDM*/*PDS* manufacturer, which can be withstood under specified conditions, defined in terms of current and time

3.79
skilled person
person with relevant education and experience to enable him or her to perceive risks and to avoid hazards which the equipment can create

[SOURCE: IEC 60050-826:2004, 826-18-01, modified – Word "(electrically)" deleted from the term, and "electricity" replaced with "the equipment" in the text.]

3.80
single-fault condition
condition in which one failure is present which could cause a hazard covered by this document

Note 1 to entry: If a *single-fault condition* results in other subsequent failures, the set of failures is considered as one *single-fault condition*.

Note 2 to entry: Examples of hazards include, but are not limited to, electric shock, fire, energy, mechanical, acoustic noise etc.

Note 3 to entry: IEC Guide 116 provides examples of hazards.

3.81
solid insulation
solid insulating material, or a combination of solid insulating materials, placed between two conductive parts or between a conductive part and a body part

Note 1 to entry: In this document, *solid insulation* does not cover liquid *insulation*.

[SOURCE: IEC 60050-903:2015, 903-04-14, modified – Example replaced with note to entry.]

3.82
surrounding air temperature
<open type> maximum *ambient temperature* of air immediately surrounding *open type* equipment inside of the ultimate *enclosure*

3.83
surroundings
parts of the *BDM/CDM/PDS* adjacent to the circuit or part under consideration

3.84
supplementary insulation
independent insulation applied in addition to basic insulation for *fault protection*

Note 1 to entry: *Basic insulation* and *supplementary insulation* are separate, each designed for *basic protection* against electric shock.

[SOURCE: IEC 60664-1:2020, 3.1.31, modified – Note to entry added.]

3.85
surge protective device
SPD
device that contains at least one non-linear *component* that is intended to limit surge voltages and divert surge currents

Note 1 to entry: An SPD is a complete assembly, having appropriate connecting means.

[SOURCE: IEC 61643-11:2011, 3.1.1]

3.86
system
set of interrelated and/or interconnected independent elements

Note 1 to entry: A *system* is generally defined with the view of achieving a given objective, for example by performing a definite function, such as grounding *system*s, wiring *system*s, power *system*s, *insulation system*s.

3.87
system voltage
voltage used to determine *insulation* requirements

Note 1 to entry: See 4.4.7.1.7 for further consideration of *system voltage*.

3.88
temporary overvoltage
overvoltage at power frequency of relatively long duration

[SOURCE: IEC 60664-1:2020, 3.1.12]

3.89
thermal memory
ability of an overload protective *system* to approximate the heating and cooling of a protected motor during operation

3.90
thermal memory retention
ability to retain a representation of the thermal state of a motor prior to tripping or loss of power

Note 1 to entry: Typically, the thermal memory retention will be used by the overload protective *system* to approximate the thermal state of the motor upon restart.

Note 2 to entry: The thermal memory retention may include an ongoing reduction of the thermal representation to reflect cooling of the motor during tripping or loss of power.

3.91
touch current
electric current passing through a human body or through an animal body when it touches one or more conductive *accessible parts* of an electrical *installation* or electrical equipment

[SOURCE: IEC 60050-826:2004, 826-11-12, modified – Word "conductive" added.]

3.92
trip
initiate a controlled rapid reduction or elimination of the transfer of energy to any device or process initiated by a detected fault or an *abnormal operating condition*

3.93
type test
conformity test made on one or more *BDM/CDM/PDS* representative of the production

[SOURCE: IEC 60050-151:2001, 151-16-16, modified – Word "items" replaced with "*BDM/CDM/PDS"*.]

3.94
visual inspection
scrutiny by eye of an item carried out either without dismantling, or with the addition of partial dismantling as required in order to arrive at a reliable conclusion as to the condition of an item

[SOURCE: IEC 60050-426:2020, 426-14-02, modified – Definition reformulated.]

3.95
working voltage
voltage, at rated supply conditions (without tolerances) and worst case operating conditions, which occurs by design in a circuit or across *insulation*

Note 1 to entry: The *working voltage* can be DC or AC. Both the RMS and recurring peak values are used.

3.96
zone of equipotential bonding
zone where all simultaneously conductive *accessible parts* are electrically connected to prevent hazardous voltages appearing between them

4 Protection against hazards

4.1 General

Clause 4 defines the minimum requirements for the design and construction of a *BDM/CDM/PDS* and *accessories* for the intended use, to ensure its safety during installation, normal operating conditions and maintenance for the *expected lifetime* of the *BDM/CDM/PDS*. Consideration is also given to minimize hazards resulting from reasonably foreseeable misuse.

Protection against hazards shall be maintained under normal *operating condition*s, *abnormal operating condition*s and *single-fault conditions,* as specified in this document.

Where the *PDS* is intended to be used together with specific equipment or *accessories*, the safety evaluation and testing shall include this, unless it can be shown that it does not affect the safety of either the *PDS* or the specific equipment.

Guidance for risk assessment for electrical equipment and systems is provided in IEC Guide 116 which is transformed for *BDM/CDM/PDS* in Annex R.

4.2 *Single-fault conditions* and *abnormal operating conditions*

BDM/CDM/PDS and *accessories* shall be designed to avoid operating modes or sequences that can cause a *single-fault condition* or *component* failure leading to a hazard, unless other measures to prevent the hazard are provided by the *installation* and are described in the installation information provided with the *BDM/CDM/PDS*, see Clause 6. The requirements in 4.2 also apply to *abnormal operating conditions* as applicable.

Circuit analysis shall be performed to identify potential hazards.

This circuit analysis shall include situations where a failure of any component, *insulation* system or *port* would result in

- a risk of electromagnetic force and thermal hazards according to 4.3,
- an impact on the decisive voltage determination according to 4.4.2,
- a risk of electric shock due to
  - degradation of the *basic protection* according to 4.4.3, or
  - degradation of the *fault protection* according to 4.4.4,
- a risk of energy hazard according to 4.5,
- a risk of degradation due to emission of flame, burning particles or molten metal of the fire according to 4.6,
- a risk of thermal hazard due to high temperature according to 4.6, and
- a risk of mechanical hazard according to 4.7.

NOTE This document does not provide any requirement to protect against chemical hazard.

The circuit analysis shall include the effect of short-circuit and open-circuit conditions. Testing is necessary unless the circuit analysis conclusively shows that no hazard will result from failure. If testing is required, compliance shall be checked by test of 5.2.4.10.

In addition to this analysis, *components* shall meet the requirements of 4.13.

Clearance, *creepage distance*s and *solid insulation* materials designed for *enhanced protection* (see 4.4.5) according to 4.4.7.4, 4.4.7.5 and 4.4.7.8 are considered to meet these requirements and do not need any further investigation.

Functional insulation on printed wiring boards (PWB) and between legs of *components* assembled on PWBs not fulfilling the requirements for *clearance* and *creepage distance* in 4.4.7.4 and 4.4.7.5 shall meet the requirement of 4.4.7.7.

Consideration shall be given to potential safety hazards associated with major *component* parts of the *PDS*, such as motor rotating parts, flammability of transformer and capacitor fluids.

The analysis shall include limited power sourced circuits, only where a failure of the limited power source circuit *component* creates a hazard in a circuit that is not sourced from a limited power source circuit.

The analysis shall also include any other investigation, study, analysis, calculation or test required to address the non-electrical hazards. Testing is necessary unless analysis shows that no hazard will result from the failure of *components* and mechanical parts.

4.3 Short-circuit and overload protection

4.3.1 General

To comply with the requirements defined in 4.2, the *BDM/CDM/PDS* shall not present a hazard under short-circuit or overload conditions (further referred as fault) at any power *port*, including phase to phase, phase to earth and phase to neutral. Adequate information shall be provided in the documentation to allow proper selection of *installation* wiring and protective devices external of the *BDM/CDM/PDS*.

If a protective system or protective device is required for short-circuit or overload protection, it shall be provided or specified.

For marking, see 6.3.9.6.

NOTE 1 Local *installation* codes will still usually require provision of such protection for the purposes of protecting the input wiring in the *installation.* In some cases, it is possible local *installation* codes supersede requirements of this document.

Protection against *overcurrent*s shall be provided for all *ports,* except

- for *ports* that comply with the requirements for limited power sources in 4.5.3, or
- if the *BDM/CDM/PDS* complies with all normal operating conditions, *abnormal operating conditions* and *single-fault conditions* in this document without such protection provided.

NOTE 2 In this document, the term *overcurrent* covers both short-circuit and overload.

When protection against *overcurrent*s is required, this may be integral to the *BDM/CDM/PDS* or it may be provided in the *installation*, and details of the required *overcurrent* protective device shall be provided in the *BDM/CDM/PDS* installation instructions in accordance with 6.3.9.6.

No protection is required against *overcurrent* to earth on *ports* that have either

- no connection to earth, or
- *enhanced protection* between *live parts* and all conductive parts connected to earth.

NOTE 3 Where *enhanced protection* is provided, a short-circuit to earth would be considered to be two faults.

Testing is not required under a *single-fault condition* to earth in *BDM/CDM/PDS* installed on an IT-*system*.

NOTE 4 Under a *single-fault condition* in an IT-*system*, no short-circuit current or a limited short-circuit current will flow. A short-circuit current would flow in an IT-*system*, when a second fault occurs. Typically, only detection is done after the first fault in an IT-*system*.

For *pluggable equipment type A*, the protective device is provided in the *installation* and shall not require any specific characteristics other than that required in IEC 60364 (all parts) or other local *installation* codes.

For *pluggable equipment type B* or *permanently connected BDM/CDM/PDS*, this protection may be provided by devices external to the *BDM/CDM/PDS*, in which case the installation instructions shall state the need for the protection to be provided in the *installation* and shall include the specifications for the required short-circuit and/or overload protection (see 6.3.9.6).

NOTE 5 IEC 60364 (all parts) provides requirements for short-circuit and overload protection of the input wiring in the installation. The above requirement ensures that the user is informed about any special characteristics of the protective devices for the protection of the PDS, in addition to the requirements in IEC 60364 (all parts) or other local installation codes.

If a protective device interrupts the neutral conductor, it shall also simultaneously interrupt all other supply conductors of the same circuit. It is permissible for the protective device to interrupt the neutral conductor after the other supply conductors of the same circuit.

Consideration shall be given to compliance with

- different type of earthing system (e.g. TN, TT, IT, star or corner-earthed in 4.4.7.1.5) as the short-circuit current to protective earth depends on the type of earthing system,
- automatic disconnection of supply in 4.4.4.4.1,
- disconnection time in 4.4.4.4.2 as required in IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017, 411.3.2, (see Annex Q), and
- alternative to automatic disconnection of supply in 4.4.4.4.3.

NOTE 6 IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017, 411.3.2, provides more information about protection against indirect contact in case of a short-circuit between *hazardous live part*s and protective earth.

NOTE 7 The short-circuit fault current to earth is expected to be up to the rated short-circuit current of the output power *port* depending on earthing system.

4.3.2 Input short-circuit rating and available *output short-circuit current*

4.3.2.1 General

The interrupting capability of the *overcurrent* protective device shall be equal to or greater than the *prospective short-circuit current* of the *mains supply* or *non-mains supply*.

For *pluggable equipment type A*, either the *PDS* shall be designed such that the *installation* provides *short-circuit backup protection*, or additional *short-circuit backup protection* shall be provided as part of the *BDM/CDM/PDS*.

For *pluggable equipment type B* or *permanently connected BDM/CDM/PDS*, it is permitted for *short-circuit backup protection* to be in the *installation*.

4.3.2.2 Rated *conditional short-circuit current* (I_{cc}) on input power *ports*

The input *prospective short-circuit current* ratings apply to *ports* intended to be connected to *mains supply* or *non-mains supply* AC or DC sources, and to other *ports* for which *overcurrent* protection is necessary.

The *BDM/CDM/PDS* manufacturer shall specify a *conditional short-circuit current* (I_{cc}) rating for compliance to 4.3.2.2, and in addition the information in either a) or b):

a) information pertaining to the *short-circuit protective device*:
   - minimum required prospective short-circuit current ($I_{cp,mr}$); and
     1) the protective device rated voltage, current, interrupt rating, I_p and I^2t at I_{cc}; or
     2) the protective device manufacturer and part number;

b) information pertaining to the *short-circuit protective device*:
   - the associated duration, and
   - if a specific protective device is used to meet this requirement, the manufacturer shall specify the protective device manufacturer and part number.

The associated duration in b) is the time the maximum symmetrical *prospective short-circuit current* was applied during the test of 5.2.4.4, 5.2.4.5 and 5.2.4.10.

Compliance is shown through evaluation according to 4.2 to determine the appropriate combination of testing according to 5.2.4.4, 5.2.4.5 and 5.2.4.10 and in order to evaluate *abnormal operating condition*s and *single-fault condition*, including *insulation* faults.

For topologies where the *BDM/CDM* includes an input transformer, special attention should be made to the fact that the fault current is significantly higher at the primary side of the transformer. This especially applies to HV topologies. See IEC 61800-2:2021, Annex A.

If it is shown by analysis that the result of one test is representative of the worst case, less severe combinations need not be tested.

For marking, see 6.2.1.4 g).

4.3.2.3 Available *output short-circuit current*

The available *output short-circuit current* ratings apply to each output *port* where overcurrent protection is required to be selected between the output of a *BDM/CDM* and the input of another *BDM/CDM*.

For each output *port*, the short-circuit evaluation to determine the maximum available *output short-circuit current* shall be performed according to 5.2.4.5.

For marking, see 6.2.1.4 g).

4.3.2.4 Combined input and output *ports*

For *ports* which are both input and output *ports*, the applicable requirements of both 4.3.2.2 and 4.3.2.3 apply.

4.3.3 Short-circuit coordination (upstream protection)

Protective devices provided or specified shall have adequate capability to interrupt the *prospective short-circuit current* specified for the *port* to which they are connected.

If internal protection of the *BDM/CDM/PDS* is not rated for the *prospective short-circuit current*, the installation instructions shall specify the upstream protective device, rated for the *prospective short-circuit current* of that *port*, which shall be used to provide protection, see 6.3.9.6. The combination of these two *overcurrent* protective devices shall be specified by the manufacturer of the protective devices as suitable for use in combination for protection of a circuit having a *prospective short-circuit current* not exceeding the rating of the upstream protective device.

NOTE IEC 60364 (all parts) provides requirements for upstream protective devices in the *installation.* The above requirement ensures that the user is informed about any special characteristics of the upstream protective devices for the protection of the *PDS*, in addition to the requirements in IEC 60364 (all parts) or other local *installation* codes.

Compliance shall be checked by *visual inspection* in 5.2.1 and by the tests of 5.2.4.5.

4.3.4 Protection by several devices

Where protective devices that require manual replacement or resetting are used in more than one pole of a supply to a given load, those devices shall be located together unless this conflicts with another safety based design consideration.

NOTE Phase segregation to prevent or reduce arc fault is a possible reason why the protective devices might not be located together.

It is permitted to combine two or more protective devices in one *component*.

Location of the protective devices shall be defined in the documentation, see 6.2.

Compliance shall be checked by *visual inspection* in 5.2.1.

4.3.5 Motor overload and overtemperature protection

4.3.5.1 Means of protection

A motor of a *PDS* shall be protected against overtemperature. Depending on the application of the motor, one or more of the following means of protection a), b), c), d) or e) for each motor driven shall be selected by the *PDS* manufacturer:

a) a thermal or electronic overload relay that complies with the applicable requirements in IEC 60947-4-1:2018;

b) a *BDM/CDM* with *electronic motor overload protection* according to 4.3.5.2, which might include

   1) *thermal memory retention* according to 4.3.5.3, and/or

   2) speed sensitivity according to 4.3.5.4;

c) a *BDM/CDM* with monitoring and trip based upon a signal from a thermal sensor mounted in or on the motor according to 4.3.5.5;

d) an embedded motor thermal protection which disconnects the motor;

e) information in accordance with 6.3.9.7.1.

NOTE 1 Selection a) and d) are the only possible motor overload protections in the case that several motors in parallel are supplied from the same *BDM/CDM* motor power *port*.

For information requirements, see 6.3.9.7 and 6.3.10.2.

NOTE 2 In the USA, compliance with US National Electrical Code ANSI/NFPA 70 for:

– overload protection according to 430.32 is achieved by a), b), c) or d); and

– overtemperature protection according to 430.126 is achieved by b) 1) and b) 2), c) or d).

4.3.5.2 *BDM/CDM* with *electronic motor overload protection*

Electronic motor overload protection shall comply with 5.2.4.6.1 to 5.2.4.6.4 and is subjected to the test requirements in 5.2.4.7.

Adjustable *electronic motor overload protection* shall not be adjustable in such a way that the limits of Table 37 are exceeded.

a) For *PDS* where motor and *BDM/CDM* are known, limits other than those in Table 37 can be specified and tested in accordance with 5.2.4.6.1 to 5.2.4.6.4.

b) For information requirements, see 6.3.9.7.2.

4.3.5.3 *BDM/CDM* with *electronic motor overload protection* with *thermal memory retention*

Electronic motor overload protection with *thermal memory retention* shall comply with 5.2.4.6.1 to 5.2.4.6.6 and is subjected to the requirements in 5.2.4.7.

4.3.5.4 *BDM/CDM* with *electronic motor overload protection* which is speed sensitive

Electronic motor overload protection that is speed sensitive shall comply with 5.2.4.6.1 to 5.2.4.6.7 and is subjected to the requirements in 5.2.4.7.

EXAMPLE Induction motor with fan mounted on the shaft.

4.3.5.5 *BDM/CDM* providing monitoring and *trip* by means of thermal sensors

BDM/CDM intended to be used with motors that have thermal protection or thermal sensor in or on the motors requiring signal *interface* shall be provided with means to connect to that protection.

Insulation requirements for the connection of the thermal protector or thermal sensor shall be taken into account. See Table 3.

For marking, see 6.3.10.2.

4.3.6 *BDM/CDM* providing current limiting control

BDM/CDM incorporating a current limiting control, i.e. a circuit that limits the output current to a set value regardless of the load on the motor, shall be tested according to 5.2.4.8.

NOTE Current limiting control can be a fixed or operator-adjustable value.

4.4 Protection against electric shock

4.4.1 General

Protection against electric shock depends on the *decisive voltage class* (*DVC*) from 4.4.2 and protection requirements from Table 3 and shall be provided by at least one of the following measures a) or b):

a) *basic protection* from 4.4.3 and *fault protection* from 4.4.4; or

b) *enhanced protection* from 4.4.5.

Protection under normal operating conditions is provided by *basic protection* 4.4.3, and protection under *single-fault conditions* is provided by *fault protection* 4.4.4.

Enhanced protection (see 4.4.5) provides protection under both normal operating conditions and *single-fault conditions*.

Basic protection, *fault protection* and *enhanced protection* may be achieved by means of *clearance* and *creepage distance*s (see 4.4.7.4 and 4.4.7.5), *solid insulation* (see 4.4.7.8) or protection by means of *enclosure* and barriers (see 4.4.3.3) or a combination of those.

Clause A.6 provides an overview about the fundamental concept for protection against electric shock within this document.

NOTE In this document, 4.4.1 to 4.4.6 have been harmonized with the concepts of the horizontal standard IEC 61140 for protection against electric shock. *Basic protection*, *fault protection*, *enhanced protection* and the combination of those measures have been implemented.

Additional protection can be provided by residual current-operated protective devices (RCD). For further information, see 4.4.8.

4.4.2 *Decisive voltage class (DVC)*

4.4.2.1 General

This document defines four voltage levels with different requirements for the protection against electric shock: *DVC As*, *DVC B*, *DVC C* and *DVC D*.

The determination of a *decisive voltage class* includes the following considerations:

a) environmental indoor unconditioned or outdoor unconditioned in Table 20;

b) normal operating conditions, *abnormal operating conditions* and *single-fault conditions*;

c) maximum *working voltage* V_{ac} RMS, V_{ac} peak and V_{dc} in Table 2, Figure 2, Figure 3 and Figure 4;

d) protection requirement between circuits and between circuits and surroundings in 4.4.2.7 or Table 3;

e) *impulse withstand voltage* in Table 2, Table 6 or Table 7 for all *DVC.*

More information for evaluation of the *working voltage* is provided in Clause A.5.

4.4.2.2 *DVC As*

A *DVC As* circuit is defined as to be safe to touch under normal operating conditions, *abnormal operating condition*s and *single-fault conditions* (see Table 2).

DVC As shall meet all of the minimum requirements a), b) and c) of 4.4.2.2:

a) voltage not exceeding the maximum steady state *working voltage* according to Table 2;
b) separation from other circuits according to 4.4.2.7 or Table 3;
c) maximum short time voltage during *abnormal operating conditions* and *single-fault conditions* according to Table 2, Figure 2, Figure 3 and Figure 4.

A circuit which does not meet all of the minimum requirements a), b) and c) of 4.4.2.2 shall be considered as either a *DVC B, DVC C or DVC D* circuit and shall be next evaluated to determine if it meets the *DVC B* requirement according to 4.4.2.3.

Circuits intended to be connected to devices external to the *BDM/CDM/PDS,* having a voltage level within *DVC As,* shall comply with the minimum requirements a), b) and c) of 4.4.2.2.

See also 4.4.6.5.3.

For marking, see 6.2.1.

4.4.2.3 *DVC B*

A *DVC B* circuit is needed if the circuit is an *interface* to *SELV* circuits or *PELV* circuits, when the nominal voltage or maximum short time voltage during *abnormal operating conditions* and *single-fault conditions* exceeds the *DVC As* voltage limits.

NOTE The maximum *DVC B* voltage is limited to the ELV limits as defined in IEC 61140 (same as *SELV* and *PELV*) under normal and *single-fault condition* (see Table 2).

DVC B shall meet all of the requirements a), b) and c) of 4.4.2.3:

a) voltage not exceeding the maximum steady state *working voltage* according to Table 2;
b) separation from other circuits according to 4.4.2.7 or Table 3;
c) maximum short time voltage during *abnormal operating conditions* and *single-fault conditions* according to Table 2, Figure 2, Figure 3 and Figure 4.

A circuit which does not meet all of the minimum requirements a), b) and c) of 4.4.2.3 shall be considered as either a *DVC C* or *DVC D* circuit and shall be next evaluated to determine if it meets the requirements for *DVC C* according to 4.4.2.4.

4.4.2.4 *DVC C*

DVC C circuits have hazardous voltages and require *basic protection* and *fault protection* or *enhanced protection* in dry, wet and salt water wet areas for the protection against electric shock.

DVC C shall meet all of the requirements a), b) and c) of 4.4.2.4:

a) voltage not exceeding the maximum steady state *working voltage* according to Table 2;
b) separation from other circuits according to 4.4.2.7 or Table 3;

c) a maximum impulse withstand voltage and temporary overvoltage if applicable according to 4.4.7.1 to 4.4.7.4.

Separation requirements to other *DVC C* circuits shall be based on the consequence of a *single-fault condition* (see 4.2) in the *insulation* and they can be either *enhanced protection*, *basic protection* or *functional insulation* and shall be based on the highest *working voltage* and *impulse withstand voltage.*

A circuit which does not meet all of the minimum requirements a), b) and c) of 4.4.2.4 shall be considered as a *DVC D* circuit and shall be next evaluated to determine if it meets the requirements for *DVC D* according to 4.4.2.5.

4.4.2.5 *DVC D*

DVC D circuits have hazardous voltages for *high-voltage BDM/CDM/PDS* and require *basic protection* and *fault protection* or *enhanced protection* in dry, wet and salt water wet areas for the protection against electric shock.

DVC D are all circuits which are not classified as *DVC As, DVC B* or *DVC C* and shall meet all of the requirements a) and b) of 4.4.2.5:

a) separation from other circuits according to 4.4.2.7 or Table 3;

b) a maximum impulse withstand voltage and temporary overvoltage according to 4.4.7.1 to 4.4.7.4, if applicable.

Separation requirements to other *DVC D* circuits shall be based on the consequence of a *single-fault condition* (see 4.2) in the *insulation* and they can be either *enhanced protection*, *basic protection* or *functional insulation* and shall be based on the highest *working voltage* and *impulse withstand voltage.*

For marking, see 6.5.7.

4.4.2.6 Determination of *decisive voltage class (DVC)*

4.4.2.6.1 General

Protective measures against electric shock depend on the *DVC* of circuits according to 4.4.2.2 to 4.4.2.5. The *DVC* in turn determines the minimum required level of protection for the circuit.

4.4.2.6.2 Limits of the *working voltage* for the *DVC*

Limits for the *working voltage* depending on the *DVC* for normal operating conditions, *abnormal operating conditions* and *single-fault conditions* are given in Table 2.

Table 2 – Voltage limits for the *decisive voltage classes*

<table>
<tr><th rowspan="2"></th><th colspan="6">Limits of working voltage</th></tr>
<tr><th colspan="4">During normal operating conditions
V</th><th colspan="2">During single-fault conditions and abnormal operating conditions
V</th></tr>
<tr><th>DVC</th><th>AC voltage (RMS)
U_{acl}</th><th>AC voltage (peak)
U_{acpl}</th><th>DC voltage (mean)
U_{dcl}</th><th>Impulse withstand voltage</th><th>Voltage
(AC peak or DC)10 ms to 200 ms</th><th>Voltage
(AC peak or DC) between 200 ms and 1 000 ms</th></tr>
<tr><td>As
(salt water wet) [e]</td><td>6</td><td>8,5</td><td>15</td><td rowspan="3">800</td><td rowspan="4">120</td><td rowspan="4">See Figure 2 and Figure 3</td></tr>
<tr><td>As
wet [c]</td><td>12</td><td>17</td><td>30</td></tr>
<tr><td>As
dry [a, d]</td><td>25 (30)</td><td>35,4 (42,4)</td><td>60</td></tr>
<tr><td>B</td><td>50</td><td>71</td><td>120</td><td rowspan="3">According to Table 6 and Table 7</td></tr>
<tr><td>C</td><td>1 000</td><td>4 500 [b]</td><td>1 500</td><td colspan="2" rowspan="2">No limit</td></tr>
<tr><td>D</td><td>No limit</td><td>No limit</td><td>No limit</td></tr>
</table>

[a] For *BDM/CDM/PDS* having only one *DVC As* circuit, the values in brackets apply.

[b] The value of 4 500 V allows all *low-voltage BDM/CDM/PDS* to be covered by Table 6 (possible reflections up to $3 \times \sqrt{2} \times 1\,000\,\text{V} = 4\,242\text{ V}$).

[c] The outdoor unconditioned rating reflects the environmental service conditions according to Table 20. This rating is permitted only if contact is possible by the tip of the finger. For information: values are derived from IEC 60364-4-41:2016, 414.4.5.

[d] The indoor unconditioned rating reflects the environmental service conditions according to Table 20. For information: this rating meets the requirements for dry locations according to IEC 61140.

[e] Values are derived from IEC 61140:2016, 5.2.6.

Clause A.5 shows three examples of different waveforms of *working voltage* and provides methods to evaluate the voltage under consideration to match with the *DVC* levels in Table 2.

The short term non-recurring touch voltage limits for *DVC As* and *DVC B* circuits during and after *abnormal operating conditions* and *single-fault condition* are given in Figure 2, Figure 3 and Figure 4. The table values for *DVC B* are steady state values from the figures.

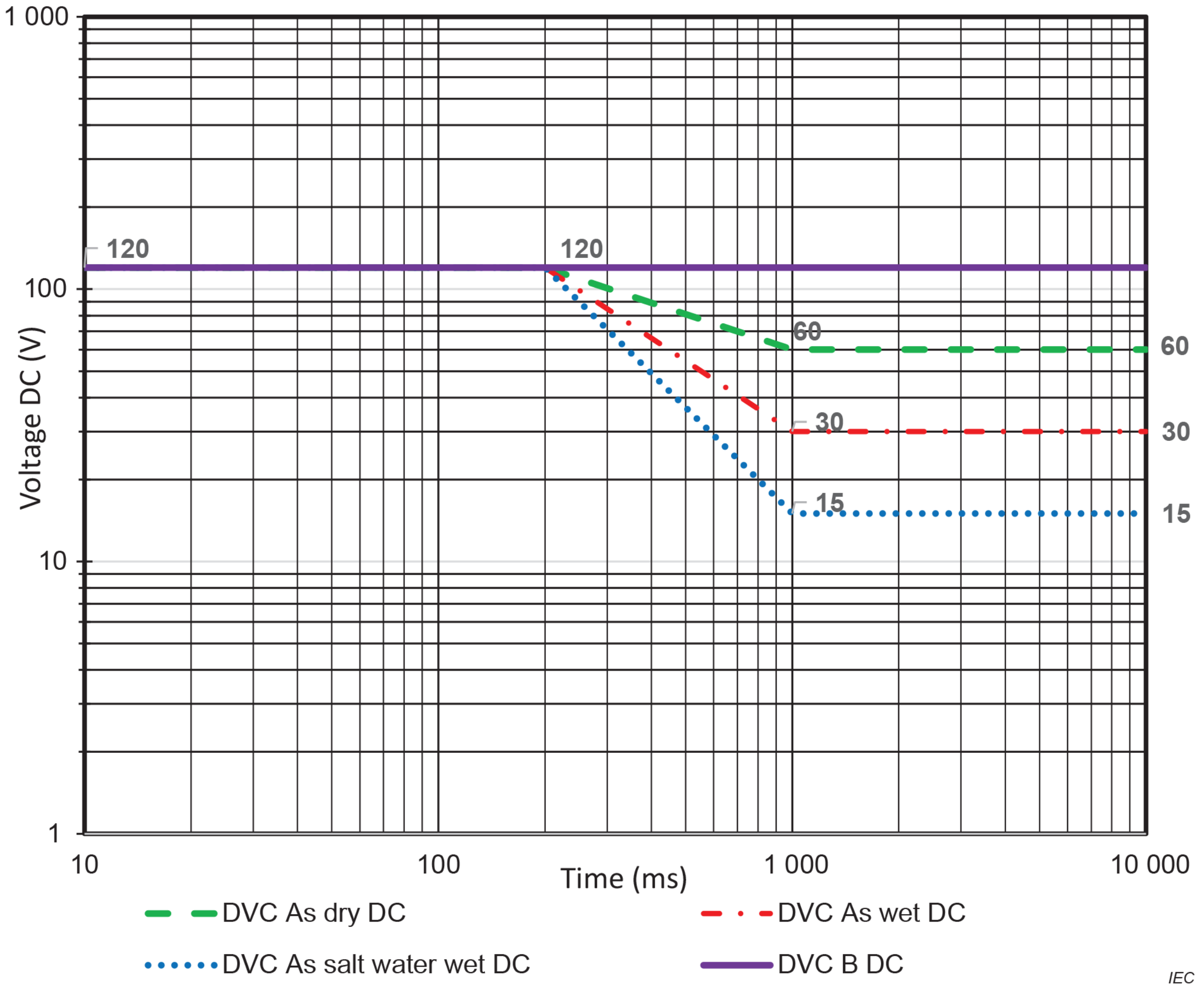


Figure 2 – Time-voltage zones for *DVC As* and *DVC B* circuits – DC

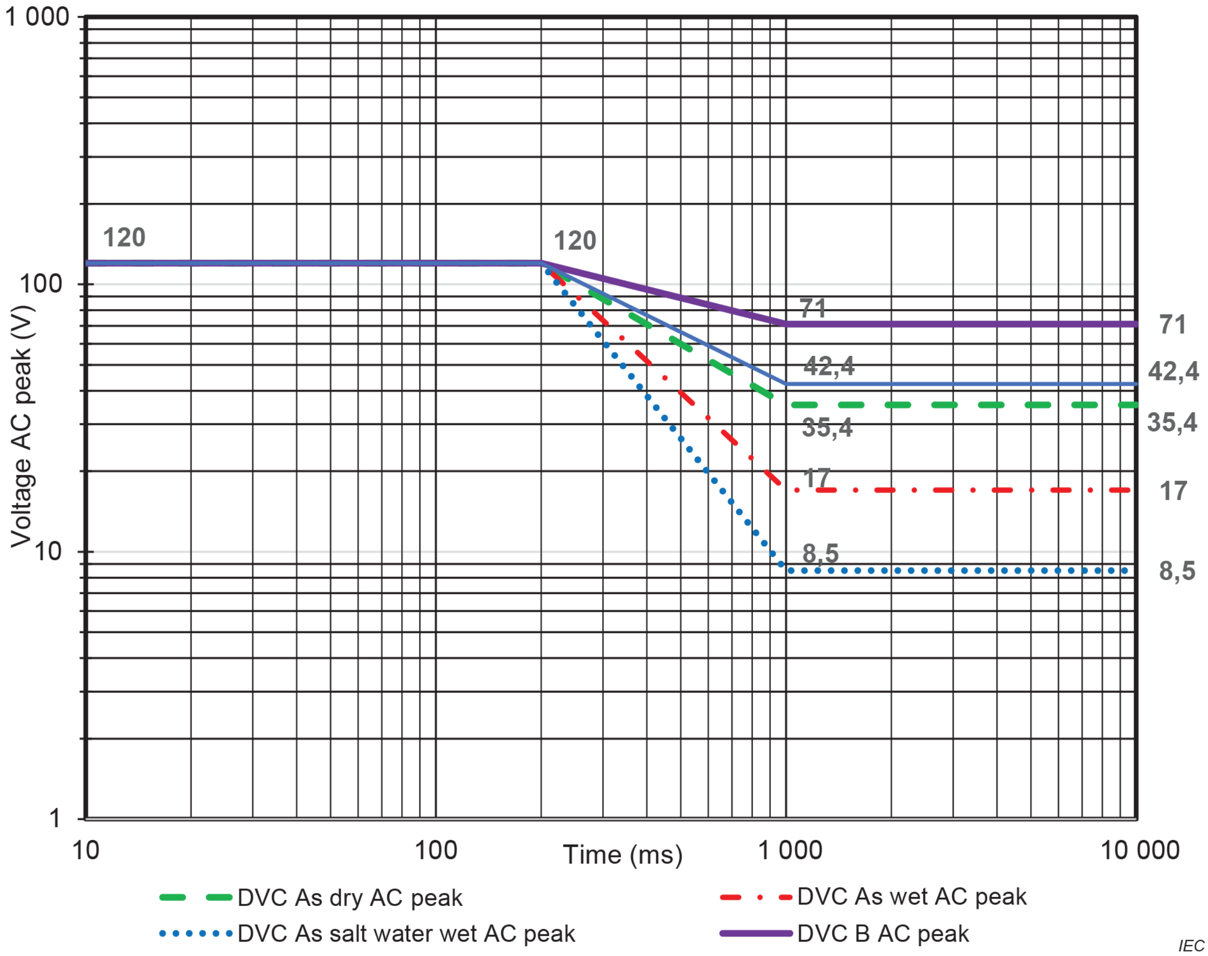


Figure 3 – Time-voltage zones for *DVC As* and *DVC B* circuits – AC peak

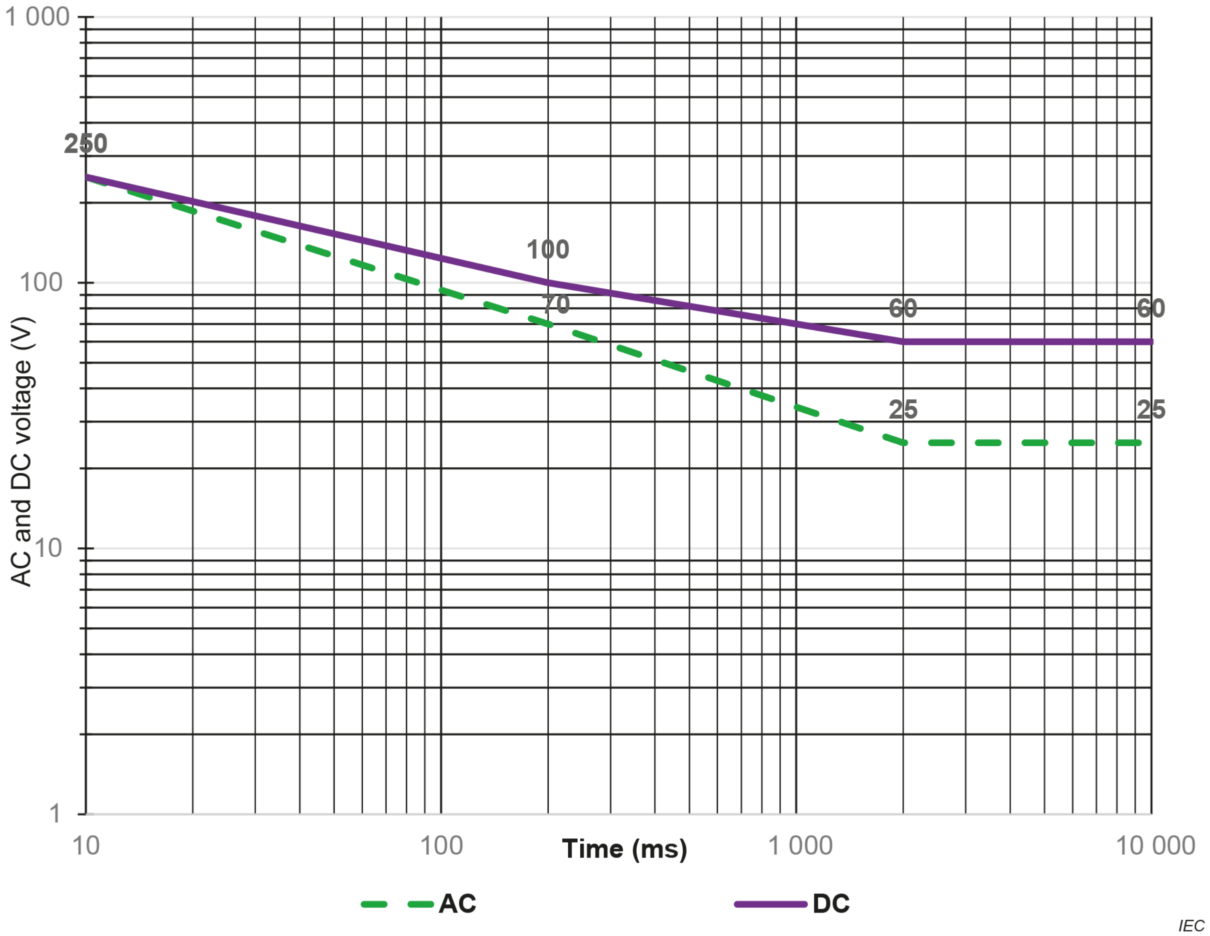


Figure 4 – Time-voltage zones for conductive *accessible parts*

Within 1 000 ms for accessible circuits and 2 000 ms for conductive *accessible parts*, the voltage shall decrease to the steady state value given in Table 2 or the fault shall be interrupted by a protective device.

Under *single-fault conditions*, where a protective device is used, the characteristics of such device shall ensure that the time-voltage limits given in Figure 4 are not exceeded. If an external protective device is used, information on characteristics of such device shall be specified by the *BDM/CDM/PDS* manufacturer in the installation manual.

For testing, see 5.2.4.

For marking, see 6.3.9.6.

4.4.2.7 Requirements for protection against electric shock

Table 3 shows possible solutions for compliance with 4.4 for the application of *basic protection* or *enhanced protection*, dependent on the *DVC* of the circuit under consideration in 4.4.2 and of *adjacent circuits*.

The requirements of this document for protection against electric shock may be fulfilled by other means than shown in Table 3, in which case failure analysis and testing shall demonstrate that the requirements of 4.1 and 4.4 are met.

Table 3 – Protection requirements for circuits under consideration

DVC of circuit under consi-deration	Protection to conductive *accessible parts* connected to PE	Protection to conductive *accessible parts* not connected to PE[c]	Protection to *adjacent circuit*				
			As **Wet**	***As*** **Dry**	***B***	***C***	***D***
As Wet	None 1 or 3	None 1	1[a] or 2[b]	*Basic protection*	*Basic protection*	*Enhanced protection*	*Enhanced protection*
As Dry	None 1 or 3	None 1	--	1[a] or 2[b]	*Basic protection*	*Enhanced protection*	*Enhanced protection*
B	*Basic protection* [d]	*Basic protection* [d]	--	--	1[a] or 2[b]	*Enhanced protection* [e]	*Enhanced protection*
C	*Basic protection*	*Enhanced protection*	--	--	--	2	*Enhanced protection*
D	*Basic protection*	*Enhanced protection*	--	--	--	--	2

Basic protection, see 4.4.3.2.

Enhanced protection, see 4.4.5.

The row "*As* Wet" covers *DVC As* wet and *DVC As* salt water wet.

1 Protection is not necessary for safety, but may be required for functional reasons according to 4.4.7.3.

2 *Basic protection* for circuit of higher voltage.

3 If the considered circuit is designated as a *SELV* circuit, *basic protection* is required from earth and from *PELV* circuits.

1 or 2 Depending on separation with other circuits.

NOTE The protection requirements in this table consider that *DVC C* and *DVC D* can be connected to mains supplies.

[a] Both circuits under consideration have the same voltage level.

[b] Both circuits under consideration have different voltage level.

[c] Also applies to conductive parts connected to functional earth.

[d] There are no protection requirement for *DVC B* to *accessible part*s in *service-access areas* or *restricted-access areas*, and refer to 4.4.3.3 and 4.11.1 for requirements about accessibility and *insulation* requirements for cable.

[e] For circuits within the voltage limits of *DVC B* which do not comply with 4.4.2.3 b), it is permitted to use *basic protection* for the circuit of higher voltage if protection against direct contact is applied to the *DVC B* circuit.

Examples are provided in Annex A to achieve protection against electric shock.

To ensure the integrity of the *insulation system* of the *BDM/CDM/PDS*, the manufacturer of a *BDM/CDM/PDS* shall state the maximum voltage allowed to be connected to each *port*.

For marking, see 6.2 and 6.3.9.1.

4.4.3 Provision for *basic protection*

4.4.3.1 General

Basic protection is used to prevent persons from touching *hazardous live parts*. It shall be provided by one or more of the measures given in a) or b):

a) protection by means of *basic insulation* of *hazardous live parts* in 4.4.3.2; or

b) protection by means of *enclosures* or barriers in 4.4.3.3.

NOTE For *low-voltage installations*, *systems* and equipment, *basic protection* in IEC 60364-4-41 generally corresponds to the formerly used "protection against direct contact", mainly with regard to failure of *basic insulation*.

4.4.3.2 Protection by means of *basic insulation* of *hazardous live parts*

Basic insulation may be provided by *solid insulation* or *clearance*.

The *basic insulation* shall be designed according to 4.4.7.2.1 for the circuits to which they are connected, taking into account the

- *impulse withstand voltage*,
- *temporary overvoltage*, and
- *working voltage*

whichever gives the most severe requirement.

It shall not be possible to remove the *insulation* without the use of a tool or key.

A conductive *accessible part* is considered to be conductive if its surface is either bare or is covered by an insulating layer that does not comply with the appropriate *insulation* requirements according to Table 3.

Any conductive *accessible part* is considered to be a *hazardous live part* if not separated from the *live part*s by at least of minimum protective requirements according to Table 3.

For testing, see 5.2.3.2 and 5.2.3.4.

Clause A.6 provides examples of the use of elements of protective measures.

4.4.3.3 Protection by means of *enclosures* or barriers

4.4.3.3.1 General

*Hazardous live part*s shall be arranged in *enclosure*s or located behind barriers which comply at least with the requirements of IP2X according to IEC 60529.

NOTE The intention to require IP2X instead of IPXXB is to limit the size of openings to less than 12,5 mm in minor dimension, as otherwise openings of up to Ø 50 mm (or 20 mm minor dimension irrespective of length) can be permitted. 12,5 mm is required to protect against solid foreign objects.

It shall only be possible to open *enclosures* or remove barriers:

- with the use of a tool or key, or
- after de-energization of these *hazardous live parts*.

Examples for openings in *enclosure*s are provided in A.6.3 and Table A.1.

For testing, see 5.2.2.2 and 5.2.2.3.

4.4.3.3.2 *Service-access areas*

Products containing circuits of *DVC B, DVC C* or *DVC D,* where the protection against electric shock is provided by the *service-access area*, do not need to have protective measures for *basic protection.* It shall be required to use a tool or a key for access to the area, and compliance with a) or b) is required.

a) The marking requirements of 6.3.9.1.1 shall apply; and
   – *accessible hazardous live parts* shall be protected by at least IPXXA; and
   – *hazardous live part*s that are likely to be touched when making adjustments shall be protected by at least IPXXB.
b) The marking requirements of 6.3.9.1.1 and 6.3.9.1.2 shall apply.

4.4.3.3.3 *Restricted-access areas*

Products containing circuits of *DVC B* or *DVC C* and intended for installation in *restricted-access areas* only do not need to have protective measures for *basic protection*, but require the use of a tool or a key for access to the area and shall be marked according to the requirements of 6.3.9.1.

Products containing circuits of *DVC D* and intended to be in a *restricted-access area* have additional requirements in 4.4.10.

4.4.3.3.4 *Open type BDM/CDM* and sub-assemblies

Open type BDM/CDM and sub-assemblies do not require protective measures for *basic protection*. This information provided with the *BDM*/*CDM* shall indicate that protection shall be provided in the *installation*.

For marking, see 6.2.1 and 6.3.6.

4.4.3.3.5 Top surfaces of *enclosures* or barriers

4.4.3.3.5.1 General

Top surfaces of *enclosure*s or barriers, which are accessible when the *BDM/CDM/PDS* is energized and below which *hazardous live part*s are located, shall fulfill the requirements of IPXXC.

NOTE Top surfaces are the projection of surfaces from vertical.

For marking, see 6.3.2.

For *BDM/CDM/PDS* with no defined top surface or that are *movable*, the requirement of IPXXC applies to all reasonably possible top surfaces.

See 5.2.2.2 for test.

4.4.3.3.5.2 Protection against vertical falling objects

Openings in *enclosure*s or barriers shall be located or constructed so that it is unlikely for vertical falling objects to enter the *enclosure* and create an electrical hazard.

Any opening shall be less than 2,5 mm in minor dimension unless an analysis according to 4.2 can prove that the construction provides adequate protection.

A ventilation opening in the top surface of a *BDM/CDM* that is not *open type* shall be covered by a hood or protective shield spaced above the opening when there are *uninsulated live parts* below the opening.

NOTE In USA and Canada, this applies to Type 1 *enclosure*.

For *movable BDM/CDM/PDS* with no defined top and bottom, this requirement applies to all sides.

Compliance is checked by *visual inspection* in 5.2.1.

For marking, see 6.3.2.

4.4.4 Provision for *fault protection*

4.4.4.1 General

Fault protection is required to prevent electric shock which can result from contact with conductive *accessible parts* during and after failure of *basic protection* in 4.4.3.

Fault protection shall be provided by one or more of the following measures a), b), c), d) or e):

a) *protective equipotential bonding* in 4.4.4.2 in combination with the external *PE conductor* in 4.4.4.3;
b) automatic disconnection of supply in 4.4.4.4;
c) *supplementary insulation* in 4.4.4.5;
d) *basic protection* between circuits in 4.4.4.6;
e) *electrically protective screening* in 4.4.4.7.

The *fault protection* shall be independent of and additional to those for *basic protection* in 4.4.3.

NOTE For *low-voltage installations*, *systems* and equipment, *fault protection* generally corresponds to protection against indirect contact as used in IEC 60364-4-41, mainly with regard to failure of *basic insulation*.

4.4.4.2 *Protective equipotential bonding*

4.4.4.2.1 General

Protective equipotential bonding is a provision for *fault protection* to enable protection against electric shock.

The *protective equipotential bonding* circuit consists of the interconnection of:

- means of connection for the *PE conductor (PE terminal(s))* of the *BDM/CDM/PDS* (see 4.4.4.3.2),
- *PE conductors* (4.4.4.3) in and between parts of the *BDM/CDM/PDS* including sliding contacts where they are part of the circuit (see Figure 5 and Figure 6),
- conductive *accessible parts* of the *BDM/CDM/PDS (*see Figure 5 and Figure 6), and
- conductive structural parts of the *BDM/CDM/PDS (*see Figure 5 and Figure 6).

Protective equipotential bonding shall be provided between conductive *accessible parts* of the *BDM/CDM/PDS* and the means of connection for the *PE conductor* to facilitate automatic disconnection of the supply according to 4.4.4.4, except

a) conductive *accessible parts* that are protected by one of the measures in 4.4.6.4, or
b) when conductive *accessible parts* are separated from *hazardous live part*s by *enhanced protection* (e.g. *double insulation* or *reinforced insulation*).

Protective equipotential bonding shall be suitably protected against mechanical damage, chemical or electrochemical degradation, electrodynamic and thermodynamic forces.

Electrical connection points of the *protective equipotential bonding* shall be corrosion-resistant.

Electrical connections of *protective equipotential bonding* circuits shall be designed so that contact pressure is not transmitted through insulating material, unless there is sufficient resilience in the metallic parts to compensate for any possible shrinkage or distortion of the insulating material.

Every connection (e.g. screwed, clamps) between *protective equipotential bonding* and other equipment shall provide durable electrical continuity and adequate mechanical strength and protection.

Screws for connecting *protective equipotential bonding* shall not serve any other purpose except where the manufacturer specifies this in the installation and maintenance manuals.

For marking, see 6.3.9.3.

If the terminal for *protective equipotential bonding* is identified by the bicolour combination green-and-yellow or the symbol IEC 60417-5019:2006-08, the terminal shall also comply with the requirements of 4.4.4.3.2.

Electrical contact to the means of connection of the *PE conductor* shall be achieved by one or more of the following means a), b), c) or d):

a) through direct metallic contact (for an example, see Figure 6, key 8);
b) through other conductive *accessible parts* or other metallic components which are not removed when the *BDM/CDM/PDS* is used as intended;
c) through a dedicated *protective equipotential bonding* conductor (see Figure 5);
d) through metal enclosures, walls or frames.

When painted surfaces (in particular powder painted surfaces) are joined together, masking of paint, paint piercing methods or a separate connection shall be made to ensure reliable contact.

Where electrical equipment is mounted on lids, *door*s, or *cover* plates, the continuity of the *protective equipotential bonding* circuit shall be ensured by a dedicated conductor or equivalent means complying with the requirements for *protective equipotential bonding*. If fasteners, hinges or sliding contacts do not provide and guarantee low enough impedance, sufficient parallel bonding is required.

Unless specified by the manufacturer and in compliance with 4.4.4.2.2, metal ducts of flexible or rigid construction and metallic cable sheaths shall not be used as *protective equipotential bonding* means. See 6.3.9.3.

Nevertheless, such metal ducts, sheaths and unused conductors shall be connected to the *protective equipotential bonding* circuit on a minimum of one end to prevent hazardous voltage due to capacitive or inductive coupling from adjacent conductors.

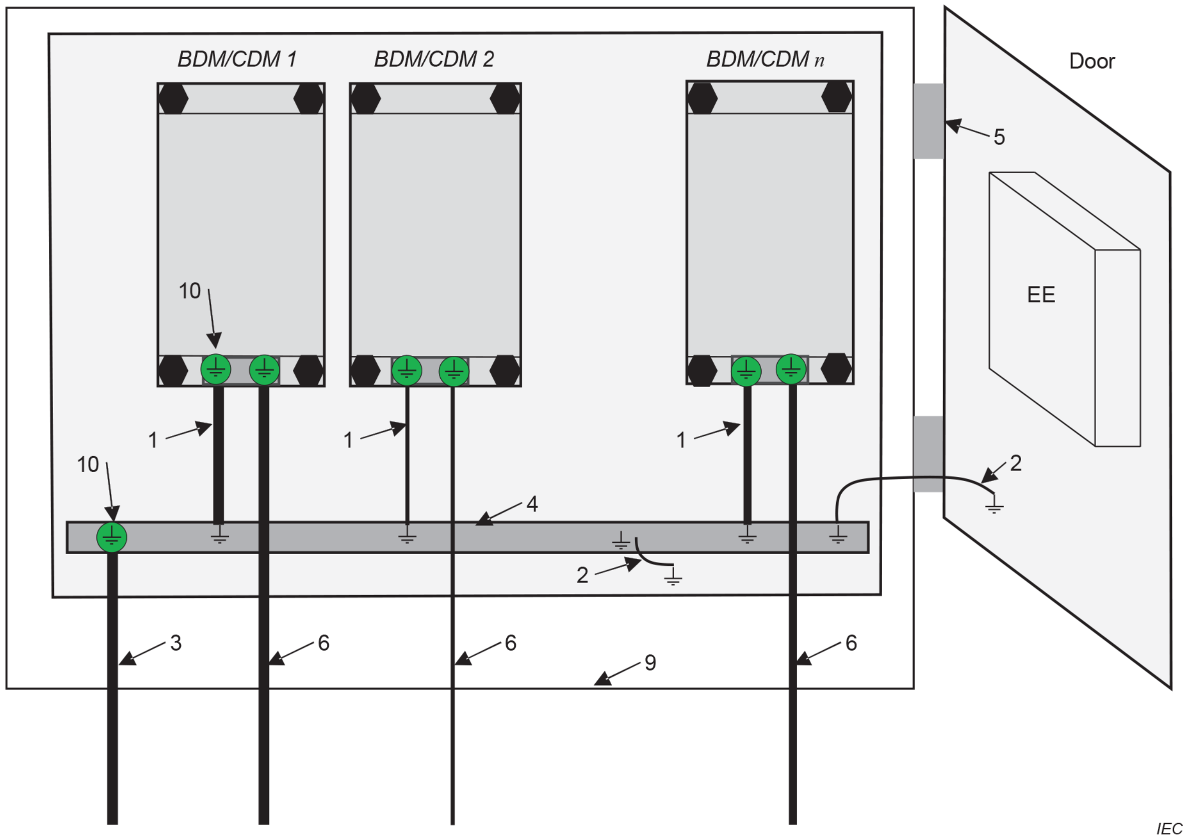
NOTE 1 For EMC reasons according to IEC 61800-3, connection on both ends can be required.

For *DVC C* and *DVC D* circuits of a *BDM/CDM/PDS*, if only one end of such ducting or sheathing is connected to the *protective equipotential bonding* circuit, the other end shall

- have provision for *basic protection* according to 4.4.3.3, or
- be connected to earth by the *protective equipotential bonding* circuit via an impedance to limit any induced voltage to a maximum of *DVC As*.

The *protective equipotential bonding* circuit shall not incorporate a *component* such as switch or *overcurrent* protective devices intended to open the circuit.

An example of *protective class I BDM/CDM* arrangement and its associated *protective equipotential bonding* is shown in Figure 5.



Key

1 *protective equipotential bonding* of *subsystems* or *BDM/CDM PE conductor* (dimensioned according to *PDS* requirements) (see 4.4.4.2 or 4.4.4.3)

2 *protective equipotential bonding* (see 4.4.4.2)

3 *PE conductor* (dimensioned according to *PDS* requirements) to *installation* earthing point (see 4.4.4.3)

4 *earth* bar

5 hinge

6 *PE conductor* to the motor or other load (see 4.4.4.3)

7 not used

8 not used

9 *enclosure* of *protective class I BDM/CDM* arrangement

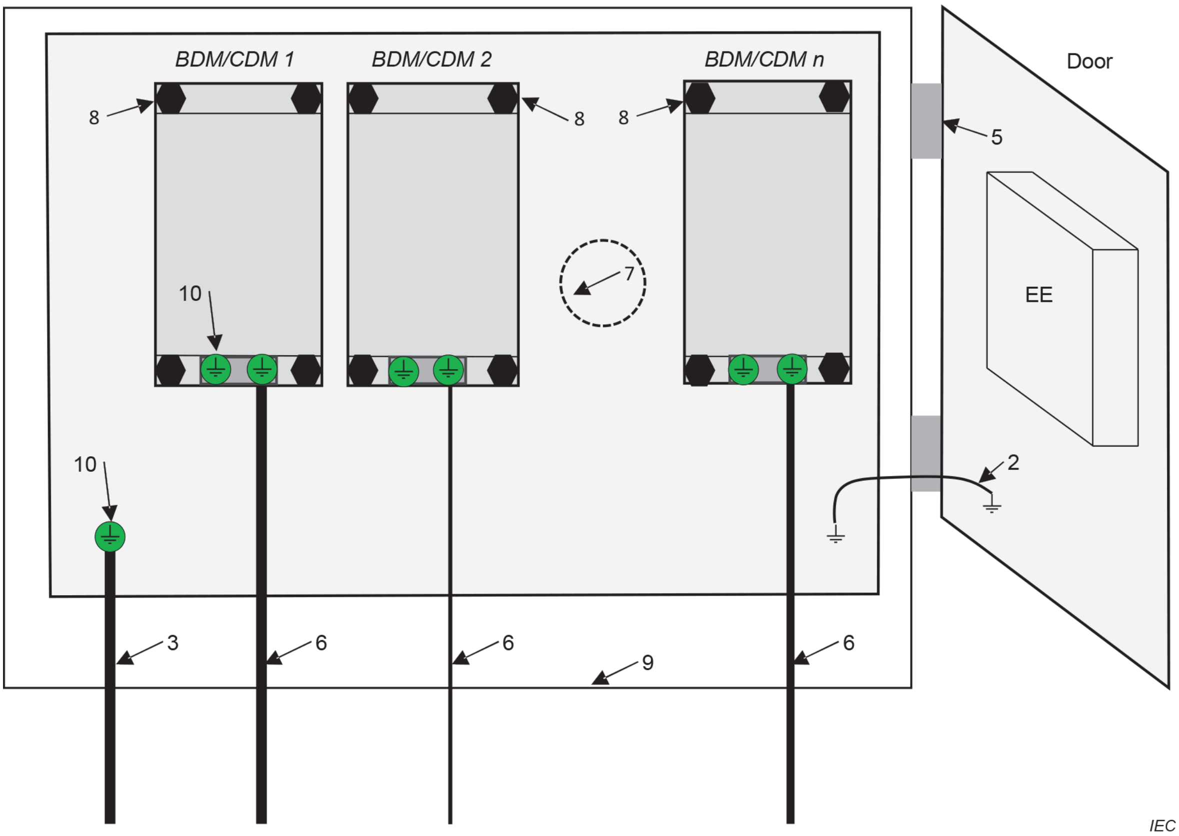
10 means of connection for the *PE conductor* (see 4.4.4.3 and 4.4.4.3.2)

EE other electrical equipment (bonded as relevant for that equipment)

NOTE Motors are not shown.

Figure 5 – Example of a *protective class I BDM/CDM* arrangement and its associated *protective equipotential bonding*

An example of *protective class I BDM/CDM* arrangement and its associated *protective equipotential bonding* through direct metallic contact is shown in Figure 6.



Key

1 not used

2 *protective equipotential bonding* (see 4.4.4.2)

3 *PE conductor* (dimensioned according to *PDS* requirements) to *installation* earthing point (see 4.4.4.3)

4 not used

5 hinge

6 *PE conductor* to the motor or other load (see 4.4.4.3)

7 metal subplate used as *protective equipotential bonding*

8 *protective equipotential bonding* through direct metallic contact according to manufacturer's installation and maintenance manuals

9 *enclosure* of *protective class I BDM/CDM* arrangement

10 means of connection for the *PE conductor* (see 4.4.4.3 and 4.4.4.3.2)

EE other electrical equipment (bonded as relevant for that equipment)

NOTE 1 Motors are not shown.

NOTE 2 Key 8 and Key 10 of *BDM/CDM* are at the same *PE conductor* potential.

Figure 6 – Example of a *protective class I BDM/CDM* arrangement and its associated *protective equipotential bonding* through direct metallic contact

NOTE 2 For more information, see IEC 60364-5-54:2011, 543.2.2.

4.4.4.2.2 Rating of *protective equipotential bonding*

All parts of a *protective equipotential bonding* between all parts of the *BDM/CDM/PDS* shall either be

a) sized in accordance with all of the requirements in 4.4.4.3 to ensure no voltage drop exceeding the limits of *DVC As* in 4.4.2.2 and Figure 4 under a *single-fault condition*, or

b) sized

- to withstand the highest stresses that can occur to the *PDS* item(s) concerned when they are subjected to a fault connecting to conductive *accessible parts*,
- to remain effective for as long as a fault to the conductive *accessible parts* persists or until an upstream protective device removes power from the part, and
- to ensure no voltage drop exceeding the limits of *DVC As* in 4.4.2.2 and Figure 4 during normal operating conditions and under a *single-fault condition*.

In case of a single means of *protective equipotential bonding* within the circuit, the *routine test* in 5.2.3.11.2 is required.

Compliance with a) does not require a *type test*.

Compliance with b) shall be checked by the *type test*s in 5.2.3.11.1.

4.4.4.3 *PE conductor*

4.4.4.3.1 General

A *PE conductor* shall be connected at all times when power is supplied to the *BDM/CDM/PDS*, unless the *BDM/CDM/PDS* complies with the requirements of *protective class II* (see 4.4.6.3) or *protective class III* (see 4.4.6.4).

Unless local wiring regulations state otherwise, the *PE conductor* cross-sectional area shall be determined from Table 4 or by calculation according to IEC 60364-5-54:2011, 543.1.

Compliance with the requirements of 4.4.4.3.3 shall be confirmed to ensure reduced risk in case of failure of the *PE conductor*.

If the *PE conductor* is routed through a plug and socket or similar means of disconnection,

- disconnection shall not be possible unless power is first removed from the part to be protected, or
- the *PE conductor* shall be the last conductor to be interrupted under normal and *single-fault conditions*.

Table 4 – *PE conductor* cross-section

Cross-sectional area of phase conductor of the *PDS* S in mm^2	**Minimum cross-sectional area of the corresponding *PE conductor* [a]** S_{PE} in mm^2
$S \leq 16$	S
$16 < S \leq 35$	16
$35 < S$	$S/2$
[a] These values are valid only if the *PE conductor* is made of the same material as the phase conductors. In case of different materials, the cross-sectional area of the *PE conductor* shall be determined in a manner which produces a conductance equivalent to that which results from the application of this table.	

The cross-sectional area of every *PE conductor* that does not form part of the multi-conductor supply cable or cable *enclosure* shall, in any case, be not less than

- 2,5 mm^2 if mechanical protection is provided (see 4.11.2.2), or
- 4 mm^2 if mechanical protection is not provided.

4.4.4.3.2 Means of connection for the *PE conductor*

BDM/CDM/PDS shall have means of connection for the *PE conductor,* located near the terminals for the respective live conductors.

The means of connection shall be corrosion-resistant and shall be suitable for the connection of conductors according to Table 4 and of cables in accordance with the wiring rules applicable at the *installation* (see 4.4.4.3.3, 4.11.11.2 and 4.11.11.3).

NOTE In the USA, the means of connection must be suitable for a conductor as specified in Section 250.122 and Table 250.122 of the US National Electrical Code ANSI/NFPA 70.

The means of connection for the *PE conductor* shall not be used as a part of the mechanical assembly of the *BDM/CDM/PDS* or for other connections.

Clamping screws and nuts for the *PE conductor* shall not serve to fix any other *component* although they may hold the terminals in place or prevent them from turning.

Connection and bonding points shall be designed so that their current-carrying capacity is not impaired by mechanical, chemical, or electrochemical influences.

Where *enclosure*s and/or conductors of aluminium or aluminium alloys are used, particular attention should be given to the problems of electrolytic corrosion.

Compliance shall be checked by visual inspection in 5.2.1.

Annex K provides further information about electrochemical corrosion.

For marking, see 6.3.9.2.2.

The marking shall not be placed on or fixed by screws, washers or other parts which might be removed when conductors are being connected.

All means of connection for the *PE conductor*, including screws and terminals, marked in accordance with 6.3.9.2.2 shall comply with the requirements of 4.4.4.3.2.

4.4.4.3.3 *Touch current* in case of failure of *PE conductor*

The requirements of 4.4.4.3.3 shall be satisfied to prevent conductive *accessible parts* from becoming dangerous in case of damage to or disconnection of the *PE conductor*.

For *pluggable equipment type A*, the *touch current* shall not exceed the limits specified in 4.4.5.4.

For all other *BDM/CDM/PDS*, one or more of the following measures a) or b) shall be applied, unless the *touch current* can be shown to be less than the limits specified in 4.4.5.4:

a) use of a permanently connected *BDM/CDM/PDS* and of one the following means:
   - a means of connection for a cross-section of the *PE conductor* of at least 10 mm^2 Cu or 16 mm^2 Al (reinforced *PE conductor)*;
   - a provision of an additional terminal for a *PE conductor* of the same cross-sectional area as the original *PE conductor (*second *PE conductor)*; or
   - the *PE conductor* is completely enclosed within electrical equipment *enclosure*s or otherwise protected throughout its length against mechanical damage (see 4.11.2.2);

   or

b) use of *permanently connected* or a *pluggable equipment type B* with a minimum *PE conductor* cross-section of 2,5 mm^2 as part of a multi-conductor power cable. A strain relief according to 4.12.6 shall be provided.

When it is intended and allowed to interconnect two or more *PDS* using one common *PE conductor*, the above *touch current* requirements apply to the maximum number of *PDS* to be interconnected, unless one of the measures in a) or b) above is used.

Compliance is checked by visual inspection in 5.2.1 and by test of 5.2.3.7.

For marking, see 6.3.9.4.

4.4.4.3.4 *PE conductor* current

During normal operating conditions, the *PE conductor* current (RMS) shall not exceed 5 % of the rated input current of the *BDM/CDM/PDS.*

NOTE This limitation of the *PE conductor* current is taken from IEC 61140.

If this limit is not achievable for functional or other reasons for *permanently connected BDM/CDM/PDS* only, in addition to the measures given in 4.4.4.3.3, the manufacturer shall provide information in the operating manual about the following protective measures, for example:

- oversized *PE conductor;* or
- *ensure a zone of equipotential bonding* within 2,5 m adjacent to the *BDM/CDM/PDS*, for example the following:
  – metallic pipes;
  – fences;
  – fixed ladders;
  – handrails;
  – connection to local earth.

  NOTE Refer to IEC 60204-1:2016, Figure 4.

For marking, see 6.3.9.4.

4.4.4.4 Automatic disconnection of supply

4.4.4.4.1 General

For automatic disconnection of supply in case of a failure of *basic insulation*,

- a *protective equipotential bonding system* shall be provided, and
- a protective device, for example fuse, circuit breaker, RCD, operated by the fault current shall disconnect one or more of the phase conductors supplying the *BDM/CDM/PDS*, as part of the *system* or *installation*.

The automatic disconnection of supply depends on an operable *protective equipotential bonding* (see 4.4.4.2) during the *expected lifetime*.

4.4.4.4.2 Interruption of the fault current within the required time

The protective device shall interrupt the fault current within a time as specified in 4.4.2.6.2 and IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017, 411.3.2.2, 411.3.2.3 and 411.3.2.4, which are reproduced in Clause Q.1.

If the protective device is not part of the *BDM/CDM/PDS,* information for selection shall be given in the installation manual.

For test, see 5.2.4.5.3 (see also 4.3.1).

For marking, see 6.3.9.6.3.

Where it is not feasible for a protective device to interrupt the supply in accordance with IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017, 411.3.2, or where the use of an RCD for this purpose is not appropriate, see 4.4.4.4.3.

However, disconnection may be requested for reasons other than protection against electric shock.

4.4.4.4.3 Automatic disconnection of supply is not feasible

In case that automatic disconnection is not feasible in conditions where

a) *BDM/CDM* with limited short-circuit current at the output power *port* is installed, or
b) the required disconnection times as specified in 4.4.4.4.2 cannot be achieved by a protective device, or
c) protection against other hazards is required (e.g. protection against thermal hazards in 4.6),

one of the following means is applicable:

1) for *installation*s with *BDM/CDM*, the voltage at the output power *port* shall be reduced to AC 50 V or DC 120 V or less by an electronic protection circuitry, which *trips* within the time specified in 4.4.4.4.2 in the event of a fault between a live conductor and the *PE conductor* or earth and the electronic protection circuitry is tested with a *type test* according to 5.2.4.5.3 and the verification according to 5.2.4.7;

   NOTE 1 One example for "electronic protection circuitry, which *trips*" is an *electronic power output short-circuit protection circuitry*.

2) supplementary *protective equipotential bonding* shall be provided in accordance with IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017, 415.2, in which the voltage between simultaneously conductive *accessible parts* shall not exceed AC 50 V or DC 120 V.

   NOTE 2 See Clause Q.2.

NOTE 3 As an example, a motor is not supplied from a *mains supply, but from a BDM/CDM* output power *port* via a long motor cable. In case of a failure in the motor, the current can be too low to operate the automatic disconnection of supply in a required time due to either limitation of the output current at the output power *port* of the *BDM/CDM* by a current limiting circuitry or by the impedance of the motor cable.

NOTE 4 Typically, the maximum available continuous current at the output power *port* against earth can be used as value for I_a (see Clause Q.2) for calculating the resistance of the supplementary *protective equipotential bonding*, to meet the voltage limits.

For marking, see 6.3.9.6.3.

4.4.4.5 *Supplementary insulation*

Supplementary insulation is an independent *insulation* applied in addition to *basic insulation* for *fault protection* and shall be dimensioned to withstand the same stresses as specified for *basic insulation*.

4.4.4.6 *Basic protection* between circuits

Basic protection between a circuit and other circuits or earth shall be achieved by *basic insulation* throughout, rated for the highest voltage present.

If any *component* is connected between the separated circuits, it shall comply with 4.4.7.1.8.

If any *component* is connected between a circuit and a circuit connected to earth, its impedance shall limit the current flow through the *component* to the values indicated in 4.4.5.4.

4.4.4.7 *Electrically protective screening*

Electrically protective screening interposed between *hazardous live parts* of a *BDM/CDM/PDS* shall consist of a conductive screen connected to the *protective equipotential bonding* of the *BDM/CDM/PDS,* whereby the screen shall be separated from *hazardous live parts* by at least *basic protection* 4.4.3.

The *electrically protective screening* and the connection to the *protective equipotential bonding system* of the *BDM/CDM/PDS* and that interconnection shall comply with the requirements of 4.4.4.2.

4.4.5 Provisions for *enhanced protection*

4.4.5.1 General

Enhanced protection shall be fully and effectively maintained under all conditions of intended use of the *BDM/CDM/PDS*. *Enhanced protection* shall provide both *basic protection* and *fault protection* and can be achieved by one or a combination of the following provisions:

a) *double insulation* in 4.4.5.2;
b) *reinforced insulation* in 4.4.5.3;
c) *protective impedance* in 4.4.5.4;
d) *electrically protective screening* in 4.4.4.7, whereby the screen is separated from *live parts* by at least *basic protection* in 4.4.3.

4.4.5.2 *Double insulation*

Double insulation shall have two or more *insulations*, where at least one *insulation* shall meet the requirement of *basic insulation* in 4.4.3.2 and another *insulation* shall meet the requirement of *supplementary insulation* in 4.4.4.5.

4.4.5.3 *Reinforced insulation*

Reinforced insulation shall be so designed as to be able to withstand electric, thermal, mechanical and environmental stresses with the same level of *insulation* as provided by *double insulation* (*basic insulation* and *supplementary insulation*, see 4.4.3.2 and 4.4.4.5), as shown by compliance with the design and test requirements for *reinforced insulation* elsewhere in this document.

4.4.5.4 Protection by means of *protective impedance*

Protective impedance shall be arranged so that, under normal operating conditions, *abnormal operating conditions* and *single-fault conditions,* the available current and discharge energy shall not exceed

- a value of 3,5 mA AC or 10 mA DC for the limitation of *touch current*, and
- a value of 0,5 mJ for the limitation of stored energy for voltages exceeding the limits of *DVC As* in Table 2.

See Clause A.3 and Clause A.4 for examples of these measures.

NOTE 1 Development of the requirements in IEC 60990, IEC 60479-1 and IEC 60479-2 for fault current with a frequency above 1 kHz will be considered for future revision.

The *protective impedance* shall be designed to withstand the *impulse withstand voltage* and *temporary overvoltage* for the circuits to which they are connected. See 5.2.3.2 and 5.2.3.4 for tests.

Compliance with the requirement of limiting the current is checked by test of 5.2.3.6.

Compliance with the requirement for the discharge energy shall be checked by performing calculations and/or measurements to determine the voltage and capacitance.

NOTE 2 A *protective impedance* designed according to 4.4.5.4 is not considered to be a galvanic connection.

4.4.6 Protective measures

4.4.6.1 General

That part of a *BDM/CDM/PDS* which meets the requirements of 4.4.6.2 is defined as *protective class I*.

That part of a *BDM/CDM/PDS* which meets the requirements of 4.4.6.3 is defined as *protective class II*.

That part of a *BDM/CDM/PDS* which meets the requirements of 4.4.6.4 is defined as *protective class III*.

Protective measures for *DVC As* circuit in *protective class I* or *protective class II* equipment are defined in 4.4.6.5.

NOTE 1 Protective class 0 according to IEC 61140:2016, 7.2, is only applicable for equipment intended for connection by means of cord and plug to circuits operating at voltage not exceeding 150 V to earth. For that reason, protective class 0 was deleted from this document.

NOTE 2 In IEC 61140, it is recommended that product standards no longer support class 0 equipment.

Compliance shall be checked by satisfying the requirements for *protective class I*, *protective class II* or *protective class III*.

BDM/CDM/PDS of protective class I, protective class II and protective class III shall be marked according to 6.3.9.2.

4.4.6.2 Protective measures for *protective class I BDM/CDM/PDS*

Protective class I BDM/CDM/PDS shall meet the requirements for

- *basic protection* in 4.4.3, and
- *fault protection* in 4.4.4 with respect to *protective equipotential bonding* in 4.4.4.2 and *PE conductor* in 4.4.4.3.

See Figure A.7, example 1.

NOTE In a typical *protective class I* equipment, the protection against electric shock is a combination of the protective measures for *protective class I, protective class II* and *DVC As* concepts.

4.4.6.3 Protective measures for *protective class II BDM/CDM/PDS*

Protective class II BDM/CDM/PDS shall meet the requirements for *enhanced protection* according to 4.4.5. In addition, the *enclosure* shall meet the requirement for *basic protection* in 4.4.3.3 with respect to accessibility to *hazardous live parts*.

NOTE In the USA and Canada, protection by means of *protective class II* methods is not applicable (US National Electrical Code ANSI/NFPA 70, Section 250.112).

See Figure A.7 example 2 or example 3.

BDM/CDM/PDS of *protective class II* shall not have means of connection for the *PE conductor*. However, this does not apply if a *PE conductor* is passed through the *BDM/CDM* to equipment series-connected beyond it.

In the passed-through *BDM/CDM*, the *PE conductor* and its means for connection shall be separated from

- conductive *accessible part*s or accessible surfaces of the *BDM/CDM/PDS* with at least *basic protection* according to 4.4.4.6, and
- *live parts* with at least *enhanced protection* according to the requirement in 4.4.5,

and designed according to the rated voltage of the series-connected equipment.

BDM/CDM/PDS of *protective class II* may have provision for the connection of an earthing conductor for functional reasons or for the damping of overvoltages. In this case, the functional earthing conductor shall be separated from

- conductive *accessible parts* or accessible surfaces of the *BDM/CDM/PDS*, and
- *live parts*

with at least *enhanced protection* according to the requirement in 4.4.5.

Compliance is checked by *visual inspection* in 5.2.1.

BDM/CDM/PDS of *protective class II* shall be marked according to 6.3.9.2.3.

4.4.6.4 Protective measures for *protective class III BDM/CDM/PDS*

BDM/CDM/PDS of *protective class* III does not need *basic protection* or *fault protection* and shall be marked according to 6.3.9.2.4.

NOTE Equipment of *protective class III* relies on being fed from a supply complying with the protective measures for *DVC As* circuits (see 4.4.2.2). Therefore, the *class III* equipment is considered safe to touch and needs no further protective measure for protection against electric shock, however it can have provision for the connection of an earthing conductor for functional reasons or for the damping of overvoltages.

4.4.6.5 Protective measures for *DVC As* circuits in *protective class I or protective class II BDM/CDM/PDS*

4.4.6.5.1 General

Protective measures shall be achieved by *enhanced protection* by one of the following means:

- *double insulation* according to 4.4.5.2;
- *reinforced insulation* according to 4.4.5.3;
- *electrically protective screening* according to 4.4.4.7 and *basic protection* according to 4.4.4.6; or
- a combination of these provisions

used in combination with one of the following means:

- limitation of voltage according to 4.4.6.5.2;
- *protective impedance* according to 4.4.5.4 comprising limitation of discharge energy and of current; or
- other means which fulfill the requirements of *DVC As*.

See Figure A.8, example 4.

The *enhanced protection* shall be fully and effectively maintained under all conditions of intended use of the *BDM/CDM/PDS*.

4.4.6.5.2 Protection by means of limited voltages

The voltage between simultaneously conductive *accessible parts* shall not be greater than *DVC As* as determined in 4.4.2.2.

See Clause A.2 for an example of this measure.

4.4.6.5.3 Provisions for connection to external *PELV* circuits or *SELV* circuits

If a *port* is intended for connection of an external *PELV* circuit or *SELV* circuit having a source voltage higher than *DVC As*,

- measures to limit the voltage to that of *DVC As* shall be taken (see A.2), or
- *basic protection* according to 4.4.3.3 shall be provided to prevent access to *hazardous live part*s.

The connection of external *PELV* circuits or *SELV* circuits to an internal circuit is permitted with the following consideration:

- without measures: only if the *DVC* of the *PELV* circuits or *SELV* circuits voltage is lower than or equal to the *DVC* selected from Table 2 for the internal circuit under consideration;
- with measures: if the *DVC* of the *PELV* circuits or *SELV* circuits voltage is higher than the *DVC* selected from Table 2 for the internal circuit under consideration.

Single-fault conditions shall be evaluated during the fault analysis in 4.2 considering as minimum

- the voltages involved under normal operating conditions and *single-fault condition* in either *BDM/CDM/PDS* or the interconnections,
- the possibility of an addition of voltages of *adjacent circuit*s,
- whether access to *hazardous live parts* is possible or not, and
- whether the circuits involved are earthed or not.

For marking, see 6.3.7 and 6.3.9.1.

4.4.7 *Insulation*

4.4.7.1 Influencing factors

4.4.7.1.1 General

4.4.7.1 gives minimum requirements for *insulation*, based on the principles of IEC 60664.

Manufacturing tolerances shall be taken into account for the distances in 4.4.7.

Insulation shall be selected after consideration of the following influences:

- working voltage (see 4.4.7.1.2);
- pollution degree (see 4.4.7.1.3);
- overvoltage category (OVC) (see 4.4.7.1.4);
- supply earthing *system* (see 4.4.7.1.5);
- *impulse withstand voltage* and *temporary overvoltage* (see 4.4.7.1.6);
- *system voltage* considering the specified supply system earthing (see 4.4.7.1.7);

- altitude, frequencies above 30 kHz and field homogeneity (see 4.4.7.4.3; 4.4.7.4.4);
- physical location of *insulation*;
- type of *insulation* (*functional insulation, basic insulation, supplementary insulation, double insulation* or *reinforced insulation*);
- material characteristics (see 4.4.7.5.1, 4.4.7.8.2, 4.4.7.8.4).

Verification of *insulation* shall be made according to the applicable tests of 5.2.2.1, 5.2.3.2, 5.2.3.4 and 5.2.3.5.

For *integrated PDS,* the motor *insulation system* shall meet the requirements of the relevant part of the IEC 60034 series. The *BDM/CDM* shall comply with the requirements of 4.4.7.

NOTE In the USA, the motor *insulation system* must meet the requirements of the relevant part of UL 1004.

Clearance and *creepage distance*s at *components* and subassemblies, which are intended to be replaced, shall be determined taken into account the worst case dimensions.

EXAMPLE Fuses, fuseholders, wiring terminals and lugs.

4.4.7.1.2 *Working voltage*

For the design of the *insulation system* according to 4.4.7, the *working voltage*, recurring peak, RMS or DC shall be determined either by calculation, or simulation or by test taking into account the voltage within circuits, against *adjacent circuit*s and against earth.

For guidance, see Clause A.5.

For test, see 5.2.3.14.

4.4.7.1.3 Pollution degree

Insulation, especially when provided by *clearance*s and *creepage distance*s, is affected by pollution which occurs during the *expected lifetime* of the *BDM/CDM/PDS*. The micro-environmental conditions for *insulation* shall be applied according to Table 5.

Table 5 – Definitions of pollution degrees

Pollution degree	Description
1	No pollution or only dry, non-conductive pollution occurs. The pollution has no influence.
2	Normally, only non-conductive pollution occurs. Occasionally, however, a temporary conductivity caused by condensation is to be expected. This (temporary) condensation may occur during periods of on-off load cycles of the *BDM/CDM/PDS*.
3	Conductive pollution or dry non-conductive pollution occurs which becomes conductive due to condensation which is to be expected.
4	The pollution generates persistent conductivity caused, for example by conductive dust or rain or snow.
NOTE Definition of the pollution degrees in Table 5 follows IEC 60664-1:2020, 4.5.2.	

The pollution degree shall be determined according to the environmental service condition for which the product is specified. See Table 20 for selection of pollution degree according to environmental classification of the *installation*.

The *insulation* may be determined according to pollution degree 2, if one of the following a), b) or c) applies:

a) instructions are provided with the *BDM/CDM/PDS* indicating that it shall be installed in a pollution degree 2 environment;

b) the specific *installation* application of the *BDM/CDM/PDS* is known to be a pollution degree 2 environment; or

c) the *BDM/CDM/PDS enclosure* or coatings applied within the *BDM/CDM/PDS* according to 4.4.7.8.4.3 or 4.4.7.8.5 provide adequate protection against what is expected in pollution degree 3 and 4 (condensation and conductive pollution).

Where internal condensation or accumulation of water occurs during normal operating condition or maintenance, measures shall be taken to prevent degradation of *insulation*. See 4.12.8.

More information for reduction of the pollution degree is provided in Annex B.

The *BDM/CDM/PDS* manufacturer shall state in the documentation the pollution degree for which the *BDM/CDM/PDS* has been designed.

For marking, see 6.3.3.

If operation in a pollution degree 4 environment is required, protection against conductive pollution shall be provided by means of a suitable *enclosure*.

For pollution degree 4, the dimensions for *creepage distance* cannot be specified. For pollution degree 3, the surface of the *insulation* may be designed to avoid a continuous path of conductive pollution, for example by means of ribs and grooves. Annex D provides further information about the evaluation of *clearance* and *creepage distance*s.

4.4.7.1.4 Overvoltage category (OVC)

The concept of overvoltage categories (based on IEC 60364-4-44 and IEC 60664-1) is used for *BDM/CDM/PDS* energized from the *mains supply* and addresses the level of overvoltage protection expected.

Four categories are considered.

- Equipment of overvoltage category IV (OVC IV) is for use at the origin of the *installation*.

  EXAMPLE 1 Electricity meters and primary *overcurrent* protection equipment and other equipment connected directly to outdoor open lines.

- Equipment of overvoltage category III (OVC III) is equipment in fixed *installations* (downstream of, and including, the main distribution board).

  EXAMPLE 2 Switches in the fixed *installation* and equipment for industrial use which is permanently connected to the fixed *installation*.

- Equipment of overvoltage category II (OVC II) is energy-consuming equipment to be supplied from the fixed *installation*.

  EXAMPLE 3 Appliances, portable tools and other household and similar loads.

  If such equipment is subjected to special requirements with regard to reliability and availability, overvoltage category III applies.

- Equipment of overvoltage category I (OVC I) is equipment for connection to circuits in which measures are taken to limit transient overvoltages to an appropriately low level.

  EXAMPLE 4 Equipment containing electronic circuits protected to this level.

NOTE Unless the circuits are designed to take the *temporary overvoltage*s into account, equipment of overvoltage category I cannot be directly connected to the *mains supply*.

The measures for reduction of the *impulse withstand voltage* shall ensure that the *temporary overvoltage*s that could occur are sufficiently limited, that their peak value does not exceed the relevant rated *impulse withstand voltage* of Table 6 or Table 7 and shall meet the requirement of 4.4.7.2.3, 4.4.7.2.4 and 4.4.7.3 as applicable.

Annex I shows examples of overvoltage category considerations for *insulation* requirements.

For *BDM/CDM/PDS* and circuits intended to be powered from a *non-mains supply*, the appropriate overvoltage category shall be determined as required by the application based on the overvoltage control provided on the supply to the *BDM/CDM/PDS* or circuit. See 4.4.7.2.4.

4.4.7.1.5 Supply earthing *system*

The following three basic types of earthing *system* are described in IEC 60364-1.

- TN-*system*: has one point directly earthed, the conductive *accessible parts* of the *installation* being connected to that point by *PE conductors*. Three types of TN-*system*, TN-C, TN-S and TN-C-S, are defined according to the arrangement of the neutral and *PE conductors*. A corner-earthed or high-leg delta TN-*system* is a TN-*system* with one point earthed.
- TT-*system*: has one point directly earthed, the conductive *accessible parts* of the *installation* being connected to earth electrodes electrically independent of the earth electrodes of the power *system*. A corner-earthed or high-leg delta TT-*system* is a TT-*system* with one point earthed.

NOTE 1 In the USA and Canada, the use of a TT-*system* is not applicable.

- IT-*system*: has all *live parts* isolated from earth or one point connected to earth through an impedance, the conductive *accessible parts* of the *installation* being earthed independently or collectively to the earthing *system*.

NOTE 2 "One point" is typically the star point or a phase but not limited to this.

NOTE 3 For further information about earthing *system* concepts (e.g. TN-C, TN-S and TN-C-S), see IEC 60364-1:2005, Clause 312.

NOTE 4 Two cases of delta-connected *systems* with one point directly earthed are corner-earthed *systems* and high-leg delta *systems*. In a corner-earthed *system*, one phase is directly earthed. In a high-leg delta *system*, one winding of a delta-connected transformer is centre-tapped, the centre tapping being directly connected to earth.

In a *BDM/CDM/PDS* designed for operation on a corner-earthed *system* or high-leg delta *system*,

- the *insulation* between phases of the *mains supply*, including the earthed phase, may be designed for *functional insulation* according to 4.4.7.3, and
- the circuits within the *BDM/CDM/PDS* directly connected to any phase of a corner-earthed *system* or high-leg delta *system* shall be separated from earthed parts by at least *basic insulation*.

For marking, see 6.2.1.4 e).

The manufacturer's selected and specified supply earthing systems in 6.2.1.4 e) are used as input for determination of the system voltage in 4.4.7.1.7.

4.4.7.1.6 Determination of *impulse withstand voltage* and *temporary overvoltage*

Table 6 and Table 7 use the *system voltage* (see 4.4.7.1.7) and overvoltage category (see 4.4.7.1.4) of the circuit under consideration to determine the *impulse withstand voltage*.

The *system voltage* is also used to determine the *temporary overvoltage*.

Table 6 – *Impulse withstand voltage* and *temporary overvoltage* versus *system voltage* for *low-voltage* circuits

Column 1	2	3	4	5	6
***System voltage* (see 4.4.7.1.7)** V **AC**	***Impulse withstand voltage*** V				***Temporary overvoltage*** [a] V **Crest value/RMS**
	Overvoltage category				
	I	**II**	**III**	**IV**	
≤ 50	330	500	800	1 500	1 770/1 250
≤ 100	500	800	1 500	2 500	1 840/1 300
≤ 150	800	1 500	2 500	4 000	1 910/1 350
≤ 300	1 500	2 500	4 000	6 000	2 120/1 500
≤ 600	2 500	4 000	6 000	8 000	2 550/1 800
≤ 1 000	4 000	6 000	8 000	12 000	3 110/2 200

Interpolation of *system voltage* is not permitted when determing the *impulse withstand voltage* for *mains supply*. Interpolation of *system voltage* is permitted when determing the *temporary overvoltage* for *mains supply*.

Interpolation of *system voltage* is permitted when determing the *impulse withstand voltage* for *non-mains supply*. Interpolation of *system voltage* is permitted when determining the *temporary overvoltage* for *non-mains supply*.

[a] The RMS values are derived using the formula (1 200 V + *system voltage*) from IEC 60664-1:2020.

Table 7 – *Impulse withstand voltage* and *temporary overvoltage* versus *system voltage* for high-voltage circuits

Column 1	2	3	4	5	6
***System voltage* (4.4.7.1.7)** V **AC**	***Impulse withstand voltage*** V				***Temporary overvoltage*** V **Crest value/RMS**
	Overvoltage Category				
	I	**II**	**III**	**IV**	
> 1 000	4 000	6 000	8 000	12 000	4 250/3 000
3 600	9 000	16 000	20 000	40 000	14 150/10 000
7 200	17 500	29 000	40 000	60 000	28 300/20 000
12 000	29 000	42 500	60 000	75 000	39 600/28 000
17 500	40 000	55 000	75 000	95 000	53 750/38 000
24 000	52 000	75 000	95 000	125 000	70 700/50 000
36 000	75 000	95 000	125 000	145 000	99 000/70 000

SOURCE: IEC 62477-2:2018, Table 101.

Interpolation is permitted.

4.4.7.1.7 Determination of the *system voltage*

4.4.7.1.7.1 For *mains supply*

The *system voltage* depends on the supply earthing systems in 4.4.7.1.5, which are selected and specified by the manufacturer in 6.2.1.4 e). For *BDM/CDM/PDS* supplied by an AC *mains supply*, the *system voltage* is

a) in Table 6 for *low-voltage*:

- in star point earthed TN-*system* and TT-*systems,* the RMS value of the rated voltage between a phase and earth;

- in corner-earthed or high-leg delta TN-*systems* and TT-*systems,* the RMS value of the rated voltage between phases;
- in three-phase IT-*systems*:
  – for determination of *impulse withstand voltage*, the RMS value of the rated voltage between a phase and an artificial neutral point (an imaginary junction of equal impedances from each phase);

    NOTE 1 For most systems, this is equivalent to dividing the phase-to-phase voltage by √3.

    NOTE 2 The phase to an artificial neutral point can be accepted due to *systems* being well balanced. Under *single-fault conditions*, the *system* voltage will temporarily change to phase-to-phase voltage, but under this *single-fault condition* the *impulse withstand voltage* is accepted to be reduced by one step according to Table 6.

  – for determination of *temporary overvoltage*, the RMS value of the rated voltage between phases;
- in single-phase IT-*systems*, the RMS value of the rated voltage between supply conductors.

b) in Table 7 for high-voltage circuits, the RMS value of the rated voltage between phases.

When the supply voltage is rectified DC, and derived from the AC *mains supply*, the *system voltage* is the RMS value of the source AC before rectification, taking into account the supply earthing *system*.

For *BDM/CDM* having rectifier bridges (e.g. 12-pulse, 18-pulse) series connected at the output, the *system voltage* for the determination of *impulse withstand voltage*s is the highest RMS value of the AC voltage before rectification at any of the rectifier bridges taking into account the supply earthing *system* (TN-*system*, TT-*system* or IT-*system*).

Voltages generated within the *BDM/CDM/PDS* by the secondaries of transformers providing galvanic isolation from the *mains supply* are considered to be *system voltage*s for the determination of impulse withstand voltages.

NOTE 3 More information is provided in IEC 61800-2:2021, Annex A.

4.4.7.1.7.2 For *non-mains supply*

For *BDM/CDM/PDS* supplied by AC or DC *non-mains supply*, the *system voltage* is the RMS value of the supply voltage between phases.

When a DC supply voltage is not derived from an AC *mains supply*, the determination of the *system voltage* and the complete *insulation system* shall comply with the requirements of IEC 62477-1:2022 and IEC 62477-2:2018.

For marking, see 6.2.1.3 a).

4.4.7.1.8 *Components* bridging *insulation*

Components bridging *basic insulation*, *supplementary insulation* or *reinforced insulation* shall comply with the requirements of the level of *insulation* they are bridging. Refer to 4.13 for *component* requirements.

4.4.7.2 *Insulation* to the *surroundings*

4.4.7.2.1 General

Insulation for *basic insulation*, *supplementary insulation* and *reinforced insulation* between a circuit and its *surroundings* in 4.4.7.2.3 and 4.4.7.2.4 shall be designed according to the most severe requirements of

- the *impulse withstand voltage*,
- the *temporary overvoltage*, and
- the *working voltage* of the circuit.

For *creepage distance*s, the RMS value of the *working voltage* is used, as described in 4.4.7.5.

For *clearance* and *solid insulation*, the *impulse withstand voltage*, the *temporary overvoltage* or the recurring peak value of the *working voltage* is used, as described in 4.4.7.2.3, 4.4.7.2.4 and 4.4.7.2.5.

NOTE 1 Examples of *working voltage* with the combination of AC, DC and recurring peak are on the DC link of an indirect voltage source converter, or the damped oscillation of a thyristor snubber, or internal voltages of a switch-mode power supply. For more information, see Clause A.5.

NOTE 2 The *impulse withstand voltage* and *temporary overvoltage* depend on the *system voltage* of the circuit, and the *impulse withstand voltage* also depends on the overvoltage category, as shown in Table 6 and Table 7.

When circuits of *DVC As* or *DVC B* are supplied from the *mains supply* through a transformer providing galvanic isolation and working at 10 kHz or more, the *insulation* between the circuit and the *surroundings* may be determined according to the *working voltage* of the circuit.

In that case, the transformer’s ability to reduce the *impulse withstand voltage*s to values less than the *impulse withstand voltage* associated with the *working voltage* determined from the applicable Table 6 or Table 7 shall be shown by test (see 5.2.3.2), simulation or calculation.

NOTE 3 The ability of a high frequency transformer to reduce *impulse withstand voltages* originates from the very low stray capacitance across the galvanic *insulation* compared to the typical grounding capacitance in the *DVC As* or *DVC B* circuit.

4.4.7.2.2 *SPD* monitoring

If the *BDM/CDM* manufacturer bundles an external SPD with their product for the purpose of overvoltage category reduction, this device shall have a monitoring circuit as required in 4.4.7.2.3 or 4.4.7.2.4 that enables the *BDM/CDM* to create an indication when the device is damaged by an overvoltage. If the SPD is internal to a *BDM/CDM*, the test of 5.2.3.15 applies.

The internal *SPD* monitoring test described above is not required on *SPD* circuits that are not part of a reduction of overvoltage category to allow for reduced *clearances*.

Compliance is determined through *visual inspection* in 5.2.1 or test according to 5.2.3.15 as appropriate.

4.4.7.2.3 Circuits connected directly to *mains supply*

Insulation between the *surroundings* and circuits which are connected directly to the *mains supply* shall be designed according to the *impulse withstand voltage*, *temporary overvoltage* or *working voltage*, whichever gives the most severe requirement.

This *insulation* is normally evaluated to withstand impulses of overvoltage category III, except that overvoltage category IV shall be used when the *BDM/CDM/PDS* is connected at the origin of the *mains supply installation*. Overvoltage category II may be used for plug-in equipment without special requirements with regard to reliability.

If measures are provided which reduce impulses of overvoltage category IV to values of category III, or values of category III to values of category II, *basic insulation* or *supplementary insulation* may be designed for the reduced values.

The requirements for *double insulation* or *reinforced insulation* shall not be reduced to values less than those required for *basic insulation* designed to withstand impulses without these measures being present.

If the devices used for this purpose can be damaged by overvoltages or repeated impulses, thus decreasing their ability to reduce impulses, they shall be monitored and an indication of their status provided according to 4.4.7.2.2.

If the *BDM/CDM/PDS* is designed to a reduced *impulse withstand voltage*, the *BDM/CDM/PDS* manufacturer shall provide overvoltage reduction measures inside the *BDM/CDM/PDS* or information shall be provided in the user manual on the proper selection of *SPDs* to be installed in the fixed *installation*. *SPDs* shall have a clamping voltage not higher than the *impulse withstand voltage* specified for the overvoltage category in Table 6 or Table 7. For correct selection of *SPDs* installed in the fixed *installation*, or within *BDM/CDM/PDS*, it is necessary to consider factors such as the *SPD's* maximum continuous operating voltage dependent on the supply *system* earthing, connection to earth, discharge energy, and the *temporary overvoltage* failure behaviour.

A preventive maintenance plan is an alternative to monitoring, as long as the overvoltage reduction remains the same.

For marking, see 6.3.9.6.4 and 6.5.1.

NOTE 1 If inherent protection or *SPD* internal in the *PDS* or as part of the *installation* is used to reduce the value of the *impulse withstand voltage,* see IEC 61643-12 for information on the selection and use of such *SPD* for *low-voltage system*s.

NOTE 2 Circuits which are connected to the *mains supply* via *protective impedances*, according to 4.4.5.4, are not regarded as connected directly to the *mains supply*.

For more information about reduction of overvoltage categories, refer to Annex I.

4.4.7.2.4 Circuits connected to *non-mains supply*

Insulation between the *surroundings* and circuits supplied from a *non-mains supply* shall be designed according to the most severe requirements of

- the *impulse withstand voltage* determined from Table 6 using the *system voltage*,
- the *temporary overvoltage* if known to exist due to the nature of the supply, and
- the *working voltage*.

These values are used to enter Table 8 for the design of *clearance*.

This *insulation* is normally evaluated to withstand impulses of overvoltage category II, except that overvoltage category III shall be used when the *BDM/CDM/PDS* is connected at the origin of the *non-mains supply installation*.

NOTE 1 The overvoltage category for *non-mains supplies* does not differ between equipment *permanently connected* in fixed *installations* and equipment not *permanently connected* to the fixed *installation*.

*Port*s connected to circuits of *DVC As* or *DVC B* for process measurement and control shall be considered as *non-mains supplies*.

If measures are provided which reduce impulses of overvoltage category III to values of category II, or values of category II to values of category I, *basic insulation* or *supplementary insulation* may be designed for the reduced value.

The requirements for *double insulation* or *reinforced insulation* shall not be reduced to values less than those required for *basic insulation* designed to withstand impulses without these measures being present.

If the devices used for this purpose can be damaged by overvoltages or repeated impulses, thus decreasing their ability to reduce impulses, they shall be monitored and an indication of their status provided according to 4.4.7.2.2.

For marking, see 6.3.9.6.4 and 6.5.1.

NOTE 2 The determined *impulse withstand voltage* based on the *system voltage* can be reduced by means of inherent protection or *SPD* internal in the *PDS* or as part of the *installation*. IEC 61643-12 provides information on the selection and use of such *SPD*.

4.4.7.2.5 *Insulation* between circuits

Insulation between two circuits shall be designed according to the circuit having the more severe requirement.

For the design of *basic protection* and *enhanced protection* between circuits, the *insulation* shall be designed according to the most severe requirements of a) or b):

a) the circuit having the more severe requirement; or
b) the *working voltage* between the circuits.

4.4.7.3 *Functional insulation*

If the failure of *functional insulation* does not produce a hazard covered by this document (electrical, thermal, fire), no specific requirements apply for the dimensioning of *functional insulation*. In other cases, the following requirements apply.

Testing is not required, except where the circuit analysis required by 4.2 shows that failure of the *insulation* could result in a hazard.

For parts or circuits that are significantly affected by external transients, *functional insulation* shall be designed according to the *impulse withstand voltage* of overvoltage category II, except that overvoltage category III shall be used when the *BDM/CDM/PDS* is connected at the origin of the *installation*.

Where measures are provided that reduce transient overvoltages within the circuit from category III to values of category II, or values of category II to values of category I, *functional insulation* may be designed for the reduced values.

Where the circuit characteristics can be shown by testing (see 5.2.3.2) to reduce impulse withstand voltages, *functional insulation* may be designed for the highest *impulse withstand voltage* occurring in the circuit during the tests.

For parts or circuits that are not significantly affected by external transients, *functional insulation* shall be designed according to the *working voltage* across the *insulation*.

The requirements of 4.4.7.7 apply.

4.4.7.4 *Clearance*

4.4.7.4.1 General

Clearance shall be determined for *functional insulation, basic insulation or supplementary insulation* directly from Table 8.

For guidance, see Clause O.1 and flowchart Figure O.1.

NOTE Standards covering the final applications where the *BDM/CDM* is used as a *component* can require more severe requirement for *clearance* (e.g. IEC 61439-1, IEC 60204-1, UL 508A).

See Annex D for examples of the evaluation of *clearance*.

Table 8 – *Clearance* for *functional insulation*, *basic insulation* or *supplementary insulation*

<table>
<tr><th>Column 1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th></tr>
<tr><th>Impulse withstand voltage [d]
(from Table 6 or Table 7)
V</th><th>Temporary overvoltage [f]
(crest value)[h]
(from Table 6 or Table 7)
V</th><th>Working voltage [f]
(recurring peak) [a]
V</th><th colspan="4">Minimum clearance in air up to 2 000 m above sea level
mm</th></tr>
<tr><th rowspan="2"></th><th rowspan="2"></th><th rowspan="2"></th><th colspan="4">Pollution degree</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th></tr>
<tr><td>N/A</td><td>≤ 110</td><td>≤ 88</td><td>0,01</td><td rowspan="5">0,2 [b c]</td><td rowspan="6">0,8 [c]</td><td rowspan="7">1,6 [c]</td></tr>
<tr><td>N/A</td><td>225</td><td>180</td><td>0,01</td></tr>
<tr><td>330</td><td>330 [e]</td><td>260 [e]</td><td>0,01</td></tr>
<tr><td>500</td><td>500 [e]</td><td>400 [e]</td><td>0,04</td></tr>
<tr><td>800</td><td>710 [e]</td><td>560 [e]</td><td>0,10</td></tr>
<tr><td>1 500</td><td>1 270 [e]</td><td>1 010 [e]</td><td>0,5</td><td>0,5</td></tr>
<tr><td>2 500</td><td>2 220 [e]</td><td>2 000 [e]</td><td>1,5</td><td>1,5</td><td>1,5</td></tr>
<tr><td>4 000</td><td>3 430 [e]</td><td>3 090 [e]</td><td colspan="4">3,0</td></tr>
<tr><td>6 000</td><td>4 890 [e]</td><td>4 410 [e]</td><td colspan="4">5,5</td></tr>
<tr><td>8 000</td><td>6 060 [e]</td><td>5 460 [e]</td><td colspan="4">8,0</td></tr>
<tr><td>12 000</td><td>9 500 [e]</td><td>8 550 [e]</td><td colspan="4">14</td></tr>
<tr><td>20 000</td><td>15 000</td><td>13 500</td><td colspan="4">25</td></tr>
<tr><td>40 000</td><td>32 300</td><td>29 000</td><td colspan="4">60</td></tr>
<tr><td>60 000</td><td>45 700</td><td>41 100</td><td colspan="4">90</td></tr>
<tr><td>75 000</td><td>59 700 [g]</td><td>53 700 [g]</td><td colspan="4">120</td></tr>
<tr><td>95 000</td><td>78 800 [g]</td><td>70 900 [g]</td><td colspan="4">160</td></tr>
<tr><td>125 000</td><td>107 000 [g]</td><td>96 000 [g]</td><td colspan="4">220</td></tr>
<tr><td>145 000</td><td>130 000 [g]</td><td>117 000 [g]</td><td colspan="4">270</td></tr>
</table>

NOTE For determination of reinforced and *double insulation*, refer to 4.4.7.4.2.

[a] This voltage is approximately 0,8 times the voltage required to break down the associated clearance for *impulse withstand voltage*s below 2 500 V and 0,9 times the voltage required to break down the associated clearance for *impulse withstand voltage*s above 2 500 V.

[b] For printed wiring board (PWB), the values for pollution degree 1 apply except that the value shall not be less than 0,04 mm.

[c] The minimum *clearance* given for pollution degrees 2, 3 and 4 are based on the reduced withstand characteristics of the associated *creepage distance* under humidity conditions (see IEC TR 63040:2016).

[d] Interpolation is permitted for *non-mains supply* but not for *mains supply*. *Clearance*s for *impulse withstand voltage* is derived from IEC 60664-1:2020, Table F.2.

[e] *Clearance*s for *temporary overvoltage* and *working voltage* are derived from IEC 60664-1:2020, Table F.8.

[f] Interpolation is permitted when *clearance* is determined from *temporary overvoltage* and *working voltage*.

[g] Values are extrapolated from IEC 60664-1:2020.

[h] Only relevant for determining insulation between surroundings and circuits.

NOTE If *clearance*s are stressed with steady-state voltages of 2,5 kV (peak) and above, dimensioning according to the breakdown values in Table 8 cannot provide operation without corona (partial discharges), especially for inhomogeneous fields. In order to provide corona-free operation, it is possible either to use larger *clearance*s, as given in IEC 60664-1:2020, Table F.9, or to improve the field distribution.

Compliance shall be checked according to 5.2.2.1.

4.4.7.4.2 *Reinforced insulation*

*Clearance*s for *reinforced insulation* shall be dimensioned to withstand the following values required for *basic insulation* in Table 8:

a) for *low-voltage BDM/CDM/PDS*:
   – the next higher impulse withstand voltage in column 1 of Table 8;
   – 1,6 times the peak *temporary overvoltage*; or
   – 1,6 times the recurring peak *working voltage*;

b) for *high-voltage BDM/CDM/PDS*:

   the value corresponding to 1,6 times the *impulse withstand voltage, temporary overvoltage or working voltage.*

4.4.7.4.3 *Clearance* for use above 2 000 m and/or above 30 kHz

Clearance for *functional insulation, basic insulation or supplementary insulation* and *reinforced insulation* for use in altitudes between 2 000 m and 20 000 m shall be calculated using a correction factor according to IEC 60664-1:2020, Table A.2, which is reproduced as Table E.1.

In the case of working voltage of fundamental frequency greater than 30 kHz,

- *clearance* for *functional insulation*, *basic insulation* or *supplementary insulation* and *reinforced insulation* due to working voltage shall be increased according to the requirements in Annex F, and
- *clearance* due to *impulse withstand voltage* and *temporary overvoltage* are still determined according to 4.4.7.4.

4.4.7.4.4 Electric field homogeneity

The dimensions in Table 8 correspond to the requirements of an inhomogeneous electric field distribution across the *clearance*, which are the conditions normally experienced in practice. If a more homogeneous electric field distribution is known to exist, the *clearance* for *basic insulation* or *supplementary insulation* may be reduced to not less than that required of IEC 60664-1:2020, Table F.2 (case B). In this case, the *impulse withstand voltage* test 5.2.3.2 shall be performed across the considered *clearance*.

If *working voltages* (recurring peak) or *temporary overvoltage*s according to Table 8 are used for the dimensioning of *clearance* and if these *clearance*s are smaller than the values of Table 8, then an AC or DC voltage test 5.2.3.4 shall be performed.

During the *impulse withstand voltage* test and AC or DC voltage test, any *insulation* layers not fulfilling at least *basic insulation* shall be removed.

Clearance for *reinforced insulation* shall not be reduced for homogeneous fields.

Compliance shall be checked according to 5.2.2.1.

4.4.7.4.5 ***Clearance* to conductive *enclosure*s**

The *clearance* between any uninsulated *hazardous live part* and the walls of a metal *enclosure* shall be in accordance with 4.4.7.4.

After the deflection tests, *clearance* between any uninsulated *hazardous live part* and the walls of a metal *enclosure* shall be in accordance with *clearance* requirements for *basic insulation* in 4.4.7.4.

NOTE The deflection of the *enclosure* is considered as a *single-fault condition*.

If the design *clearance* is at least 12,7 mm and the *clearance* required by Table 8 does not exceed 8 mm, the deflection tests may be omitted.

Compliance is checked by *visual inspection* in 5.2.1 and by test of 5.2.2.4.2.

4.4.7.5 ***Creepage distance*s**

4.4.7.5.1 General

*Creepage distance*s shall be large enough to prevent long-term degradation of the surface of solid insulators.

For guidance, see Clause O.2 and flowchart Figure O.2.

See Annex D for examples of the evaluation of *creepage distance*s.

4.4.7.5.2 Insulating material groups

Insulating materials are classified into four groups according to Table 9, corresponding to their comparative tracking index (CTI) and performance level category (PLC).

Table 9 – Insulating materials classification

Insulating material group	IEC [a]/CSA [b]	PLC [c]
Insulating material group I	CTI ≥ 600	0
Insulating material group II	600 > CTI ≥ 400	≤ 1
Insulating material group IIIa	400 > CTI ≥ 175	≤ 3
Insulating material group IIIb	175 > CTI ≥ 100	≤ 4

NOTE 1 CTI according to IEC 60112, CSA C22.2 No. 0.17 and CTI PLC according to UL 746A will give a comparable level of safety based on practice.

NOTE 2 Some material or *component* datasheets can specify a proof tracking index (PTI) according to IEC 60112. The PTI according to IEC 60112 is considered equivalent to the CTI according to IEC 60112 for the purpose of this document.

[a] CTI (comparative tracking index) tested according to IEC 60112:2020, 6.2.

[b] CTI (comparative tracking index) tested according to CSA C22.2 No. 0.17.

[c] PLC (performance level category) according to UL 746A. The numeric PLC number (not the performance) shall be less than or equal to the value in the column.

Creepage distance requirements for PWBs exposed to environmental conditions of pollution degree 3 shall be determined based on Table 10 pollution degree 3 under "Other insulators".

If the *creepage distance* path is ribbed, then the *creepage distance* of insulating material of group I may be applied using insulating material of group II and the *creepage distance* of insulating material of group II may be applied using insulating material of group III. The *clearance* of the ribs shall be equal to or exceed the dimension X in Table D.1. For pollution degree 2 and 3, the ribs shall be at least 2 mm high.

For inorganic insulating materials, for example glass or ceramic, which do not track, the *creepage distance* may equal the associated *clearance*, as determined from 4.4.7.4.

4.4.7.5.3 Determination

*Creepage distance*s for *functional insulation*, *basic insulation* and *supplementary insulation* shall be dimensioned according to Table 10.

Table 10 – *Creepage distances*

Column 1	2	3	4	5	6	7	8	9	10	11	12
***Working voltage* (RMS)**	**PWBs [a]**		**Other insulators**								
	Pollution degree		**Pollution degree**								
	1	**2**	**1**	**2**				**3**			
				Insulating material group				**Insulating material group**			
	[b]	[c]	[b]	**I**	**II**	**IIIa**	**IIIb**	**I**	**II**	**IIIa**	**IIIb**
V	mm	mm	mm	mm	mm	mm		mm	mm	mm	
≤ 2	0,025	0,04	0,056	0,35	0,35	0,35		0,87	0,87	0,87	
5	0,025	0,04	0,065	0,37	0,37	0,37		0,92	0,92	0,92	
10	0,025	0,04	0,08	0,40	0,40	0,40		1,0	1,0	1,0	
25	0,025	0,04	0,125	0,50	0,50	0,50		1,25	1,25	1,25	
32	0,025	0,04	0,14	0,53	0,53	0,53		1,3	1,3	1,3	
40	0,025	0,04	0,16	0,56	0,80	1,1		1,4	1,6	1,8	
50	0,025	0,04	0,18	0,60	0,85	1,20		1,5	1,7	1,9	
63	0,04	0,063	0,20	0,63	0,90	1,25		1,6	1,8	2,0	
80	0,063	0,10	0,22	0,67	0,95	1,3		1,7	1,9	2,1	
100	0,10	0,16	0,25	0,71	1,0	1,4		1,8	2,0	2,2	
125	0,16	0,25	0,28	0,75	1,05	1,5		1,9	2,1	2,4	
160	0,25	0,40	0,32	0,80	1,1	1,6		2,0	2,2	2,5	
200	0,40	0,63	0,42	1,0	1,4	2,0		2,5	2,8	3,2	
250	0,56	1,0	0,56	1,25	1,8	2,5		3,2	3,6	4,0	
320	0,75	1,6	0,75	1,6	2,2	3,2		4,0	4,5	5,0	
400	1,0	2,0	1,0	2,0	2,8	4,0		5,0	5,6	6,3	
500	1,3	2,5	1,3	2,5	3,6	5,0		6,3	7,1	8,0	
630	1,8	3,2	1,8	3,2	4,5	6,3		8,0	9,0	10,0	
800	2,4	4,0	2,4	4,0	5,6	8,0		10,0	11	12,5	[e]
1 000	3,2	5,0	3,2	5,0	7,1	10,0		12,5	14	16	
1 250	4,2	6,3	4,2	6,3	9	12,5		16	18	20	
1 600	[f]	[g]	5,6	8,0	11	16		20	22	25	
2 000			7,5	10,0	14	20		25	28	32	
2 500			10,0	12,5	18	25		32	36	40	
3 200			12,5	16	22	32		40	45	50	
4 000			16	20	28	40		50	56	63	
5 000			20	25	36	50		63	71	80	
6 300			25	32	45	63		80	90	100	
8 000			32	40	56	81		100	110	125	
10 000			40	50	71	100		125	140	160	
12 500			50	63	90	125		[d]	[d]	[d]	
16 000			63	80	110	150					
20 000			80	100	140	200					
25 000			100	125	180	250					
32 000			125	160	220	320					
Interpolation is permitted.											

[a]	These columns also apply to *components* and parts on PWBs, and to other *creepage distance*s with a comparable control of tolerances.
[b]	All material groups.
[c]	All material groups except IIIb.
[d]	Values for *creepage distance*s are not determined for this range.
[e]	Insulating materials of group IIIb are not normally recommended for pollution degree 3 above 630 V.
[f]	Above 1 250 V, use the values from column 4.
[g]	Above 1 250 V, use the values from columns 5 to 8, using the appropriate material group and *working voltage*.

*Creepage distance*s for *reinforced insulation* shall be twice the distances required for *basic insulation*.

For fundamental frequencies greater than 30 kHz, additional requirement can apply in Clause F.3 and Table F.3 for the *working voltage*.

In all cases, the associated *creepage distance* is not permitted to be smaller than the required *clearance*.

Compliance of *creepage distance*s shall be checked according to 5.2.2.1 and according to Annex F if applicable.

4.4.7.6 Coating or potting

A coating or potting may be used to provide *insulation* or to protect a surface against pollution and to allow a reduction in *clearance* and *creepage distance*s (see 4.4.7.8.4.3 and 4.4.7.8.5).

If used as *solid insulation* for *basic protection, fault protection* and *enhanced protection*, the coating or potting shall comply with the requirements of 4.4.7.8.1 and 4.4.7.10.

If used to protect against pollution, the requirements for type 1 protection in 4.4.7.8.4.3 apply.

NOTE 1 Typically, coating or potting is used for *components* and subassemblies.

NOTE 2 Coating for improvement of the *insulation system* is well known in industries as conformal coating.

4.4.7.7 *Clearance* and *creepage distances* for *functional insulation* on PWB and *components* assembled on PWB

Clearance and *creepage distances* for *functional insulation* on PWB and *components* assembled on PWB shall comply with the requirements of 4.4.7.4 and 4.4.7.5.

Decreased *clearance* and *creepage distances* on PWB are permitted when all the following are satisfied:

a) the PWB has minimum flammability rating of V-0 (see IEC 60695-11-10:2013);
b) the PWB base material has a minimum CTI of 100;
c) the PWB complies with the PWB short-circuit test (see 5.2.4.11).

Decreased *clearance* and *creepage distances* for *components* assembled on PWB are permitted when

d) used in pollution degree 1 or 2 environment,
e) used in overvoltage category I, and
f) the assembled PWB complies with the PWB short-circuit test (see 5.2.4.11).

In this case, the *component* manufacturer’s specification may be used.

4.4.7.8 *Solid insulation*

4.4.7.8.1 General

Materials selected for *solid insulation* shall be able to withstand the stresses occurring. These include mechanical, electrical, thermal, climatic and chemical stresses which are to be expected in normal use. *Insulation* materials shall also be resistant to ageing during the *expected lifetime* of the *BDM/CDM/PDS*.

For fundamental frequencies of the *working voltage* greater than 30 kHz, Clause F.4 shall be taken into account.

NOTE *Solid insulation* can be stressed by the corona effect, especially for inhomogeneous fields. In order to provide corona-free operation, it is possible either to use additional *clearance*s or to improve the field distribution. This phenomenon is proportional to the increase of the voltage stress across the *insulation* system.

Tests shall be performed on *components* and sub-assemblies using *solid insulation* according to 4.4.7.10, in order to ensure that the *insulation* performance has not been compromised by the design or manufacturing process.

Components shall comply with 4.13.

4.4.7.8.2 Material requirements

Material that is distanced as specified below to uninsulated *live part*s or switching contacts of circuits other than limited power sources according to 4.5.3 shall be suitable for the maximum temperature determined by the temperature rise test of 5.2.3.10. Consideration shall be given as to whether or not the material additionally provides mechanical strength and whether or not the part can be subject to impact during use.

The material shall have any flammability rating and comply with the applicable HWI, HAI, and CTI values of Table 11 based on its flammability rating in accordance with the following:

- Hot-wire resistance to ignition (HWI)

  Materials that are in direct contact or within the distance according to Table 12 of uninsulated *live part*s of circuits shall comply with HWI (hot wire ignition) according to Table 11 or the glow wire test described in 5.2.5.3 at a test temperature of 850 °C or at a lower test temperature, but not less than 550 °C, depending on the classification of the use of the *BDM/CDM*, according to IEC 60695-2-11:2021, Figure A.1.

- High-current arc resistance to ignition (HAI)

  Materials that are within 12,7 mm of switching contacts of circuits and materials that are within the distance according to Table 12 of uninsulated *live part*s of circuits shall comply with HAI according to Table 11.

- Comparative tracking index (CTI)

  Materials that are within the distance according to Table 12 of uninsulated *live part*s of circuits where there is a *creepage distance* of less than 12,7 mm to other uninsulated *live part*s of different potential shall comply with CTI according to Table 11.

The following thermoplastic insulating materials used shall comply with the ball pressure test according to IEC 60695-10-2:2014:

- in contact with *hazardous live parts* (direct support of *live part*);
- as part of the *enclosure.*

The rated temperature for parts in contact with *hazardous live parts* shall be not less than the *ambient temperature* plus the maximum temperature rise of the parts under consideration measured during test of 5.2.3.10 and not less than 95 °C.

If the manufacturer of the insulating material provides data to demonstrate compliance with the above requirements, no further testing is required.

Table 11 – *Insulation* material requirements

	HWI		HAI		CTI		
Flammability rating [a]	**Time to ignition [b]**	**PLC [c]**	**Arcs to ignition [d]**	**PLC [c]**	**IEC 60112 [e]**	**PLC [c,e]**	**CSA C22.2 no. 0.17 [f]**
HB	≥ 30 s	≤ 2	≥ 60	≤ 1	≥ 100	≤ 3	≥ 175
V-2	≥ 30 s	≤ 2	≥ 30	≤ 2	≥ 100	≤ 3	≥ 175
V-1	≥ 15 s	≤ 3	≥ 30	≤ 2	≥ 100	≤ 3	≥ 175
V-0 or better	≥ 7 s	≤ 4	≥ 15	≤ 3	≥ 100	≤ 3	≥ 175

NOTE 1 For Canada, compliance to "time to ingnition" and "arcs to ignition" must be demonstrated according to CSA C22.2 No. 0.17.

NOTE 2 Flame ratings according to IEC 60695-11-10:2013, IEC 60695-11-20:2015 and UL 94 are considered equivalent because these standards have been harmonized. HWI and HAI performance according to the tests in 5.2.5.4 and 5.2.5.2 and the HWI and HAI PLC according to UL 746A will give a comparable level of safety based on practice. CTI performance according to IEC 60112 and CTI PLC according to UL 746A will give a comparable level of safety based on practice.

NOTE 3 Some material or *component* datasheets can specify a proof tracking index (PTI) according to IEC 60112. The PTI according to IEC 60112 is considered equivalent to the CTI according to IEC 60112 for the purpose of this document.

[a] According to IEC 60695-11-10:2013, IEC 60695-11-20:2015, UL 94 or CSA C22.2 No.0.17.

[b] As determined by test according to 5.2.5.4 or material manufacturer’s data.

[c] PLC (performance level category) according to UL 746A. The numeric PLC number (not the performance) shall be less than or equal to the value in the column.

[d] As determined by test according to 5.2.5.2 or material manufacturer’s data.

[e] Consideration of 4.4.7.5 may also be necessary.

[f] A material having a minimum CTI value of 100 may be used if the voltage involved is 250 V or less.

Table 12 – Distance to uninsulated *live parts* for consideration of HWI, HAI and CTI

Pollution degree	**Distance** mm
1	0,25
2	1,0
3	1,5

No further evaluation is required when generic materials of Table 13 are used with the minimum thickness of Table 13, and the measured temperature during the temperature rise test shall not exceed the temperature limits of Table 13.

Table 13 – Generic materials for *insulation* material

Generic material	Minimum thickness mm	Maximum temperature °C
Any cold-moulded composition	No limit	No limit
Ceramic, porcelain	No limit	No limit
Diallyl phthalate	0,7	105
Epoxy	0,7	105
Melamine	0,7	130
Melamine-phenolic	0,7	130
Phenolic	0,7	150
Unfilled nylon	0,7	105
Unfilled polycarbonate	0,7	105
Urea formaldehyde	0,7	100

Compliance is checked

- by *visual inspection* in 5.2.1,
- the temperature rise test in 5.2.3.10,
- the high current arcing ignition test 5.2.5.2, and
- the glow-wire test in 5.2.5.3 or the hot wire ignition test in 5.2.5.4.

4.4.7.8.3 Thin sheet or tape material

4.4.7.8.3.1 General

Subclause 4.4.7.8.3 applies to the use of thin sheet or tape materials less than 0,7 mm thick in assemblies such as wound *components* and bus bars.

Subclause 4.4.7.8.3 does not apply for *components* having a product safety standard. See 4.13.

Insulation consisting of thin sheet or tape materials is permitted, provided that it is protected from mechanical damage and is not subject to mechanical stress under normal use.

Where more than one layer of *insulation* is used, there is no requirement for all layers to be of the same material.

One layer of *insulation* tape wound with more than 50 % overlap is considered to constitute two layers.

NOTE *Basic insulation*, *supplementary insulation* and *double insulation* can be applied as a pre-assembled *system* of thin materials.

4.4.7.8.3.2 Thin sheet or tape material thickness and number of layers

Table 14 specifies the required number of layers depending on the thickness of the thin sheet material and the type of *insulation*.

Table 14 – Requirements based on thin sheet material thickness

Type of *insulation*	Thickness of each layer of sheet or tape material		Requirements
	< 0,2 mm	**≥ 0,2 mm**	
Basic insulation **or** ***supplementary insulation***	At least 1 layer	At least 1 layer	4.4.7.8.1, 4.4.7.10.2
Double insulation	--	At least 2 layers	Each layer: 4.4.7.8.1, 4.4.7.10.2 and all layers together 4.4.7.10.3
	At least 3 layers	--	Each layer: 4.4.7.8.1, 4.4.7.10.2 and any 2 layers together 4.4.7.10.3
Reinforced insulation	At least 3 layers of non-separable material which cannot be tested separately	At least 1 layer, minimum thickness of 0,4 mm	4.4.7.8.1, 4.4.7.10.3

Compliance shall be checked by the tests described in 5.2.3.1 to 5.2.3.5.

For any *high-voltage* section of a *BDM/CDM/PDS*, a partial discharge test (see 5.2.3.5) is required in any case where more than one layer is used. For low voltage sections of a *high voltage BDM/CDM/PDS*, refer to 4.4.7.10.3.

When a *component* or sub-assembly makes use of thin sheet insulating materials, it is permitted to perform the tests on the *component* rather than on the material.

Material test is provided in 5.2.3.13.

4.4.7.8.4 Printed wiring boards (PWBs)

4.4.7.8.4.1 General

Printed wiring boards material shall have a flammability rating of V-2 or better and shall comply with the insulating material group IIIb or better according to Table 9.

NOTE In USA, printed wiring boards must conform with the Standard for Printed-Wiring Boards, UL 796, or the Standard for Flexible Materials Interconnect Constructions, UL 796F as appropriate, and must be identified as suitable for direct support of *live parts*.

The requirements of 4.4.7.8.4 do not apply to printed wiring boards which contain only limited power sources according to 4.5.3.

PWB shall meet the appropriate requirements of 4.4.7.10.1 and

- 4.4.7.10.2 for *basic insulation*/*supplementary insulation*, or
- 4.4.7.10.3 for *double insulation*/*reinforced insulation,* or
- 4.4.7.7 for *functional insulation.*

4.4.7.8.4.2 Inner layers of multi-layer printed wiring boards

Insulation (preimpregnated fibres, prepreg) between conductor layers in multi-layer PWBs and metal core PWBs is *solid insulation* according to IEC 60664-1:2020 and shall meet the applicable requirements of 4.4.7.8.1 and 4.4.7.8.4.1.

NOTE 1 For more information, see IEC 60664-3:2016, Clause 1.

The requirements in 4.4.7.8.3 for thin sheet or tape material are not applicable; however, a minimum overall material thickness of 0,4 mm for *double insulation* and *reinforced insulation* apply to the final PWB.

Insulation between adjacent tracks on the same conductor inner layer shall be treated as either

a) a *creepage distance* for pollution degree 1 and a *clearance* as in air according to Table 8 and Table 10 (see Figure D.14), or
b) *solid insulation*, in which case
   – it shall meet the applicable requirements of 4.4.7.8.4.1,
   – it shall meet the minimum distances from Table O.1 for *basic insulation* and *reinforced insulation*,
   – the requirements for *clearance* and *creepage distance*s according to Table 8 and Table 10 do not apply,
   – one PWB sample shall be preconditioned according to 5.2.3.16 followed by a *type test* according 5.2.3 as specified in 4.4.7.8.4.1, and
   – no *routine test* on the final PWB is required.

NOTE 2 For FR4 material, the voltage strength per thickness can be estimated with 30 kV/mm.

Inner layer of PWB is shown in **Figure D.14**.

4.4.7.8.4.3 Use of coating materials

A coating material used to provide *functional insulation*, *basic insulation*, *supplementary insulation* or *reinforced insulation* shall meet the requirement as specified below.

Type 1 protection (as defined in IEC 60664-3) improves the microenvironment of the parts under protection. The *clearance* and *creepage distance* of Table 8 and Table 10 for pollution degree 1 apply under the protection. Between two conductive parts, it is a requirement that one or both conductive parts, together with all the *clearance* and *creepage distances* between them, are covered by the protection.

Type 2 protection is considered to be similar to *solid insulation*. Under the protection, the requirements for *solid insulation* specified in 4.4.7.8 are applicable, including the coating material itself, and *clearance* and *creepage distances* shall not be less than those specified in IEC 60664-3:2016, Table 1, which is reproduced as Table O.1. The requirements for *clearance* and *creepage distance* in Table 8 and Table 10 do not apply. Between two conductive parts, it is a requirement that both conductive parts, together with the *clearance* and *creepage distances* between them, are covered by the protection so that no airgap exists between the protective material, the conductive parts and the printed boards.

The coating material used to provide type 1 and type 2 protection shall be designed to withstand the stresses anticipated to occur during the *expected lifetime* of the *BDM/CDM/PDS*.

A *type test* on representative PWB shall be conducted according to IEC 60664-3:2016, Clause 5. Number of samples is defined in IEC 60664-3:2016. Preconditioning according to 5.2.3.16 is required before *type test*.

No *routine test* is required.

4.4.7.8.5 Potting materials

A potting material may be used to provide *solid insulation* or to act as a coating to protect against pollution. If used as *solid insulation* for *basic protection, fault protection* and *enhanced protection*, it shall comply with the requirements of 4.4.7.8.4.2 b) except replace the terms "PWB" with "potted sample".

A *visual inspection* in 5.2.1 shall be carried out following the test specified in 4.4.7.8.4.2 b) to demonstrate that the test sample does not show

- blistering,
- swelling,
- separation from the base material,
- cracks,
- voids, and
- areas with adjacent unprotected conductive parts, with the exception of lands.

If used to protect against pollution, the requirements for type 1 protection in 4.4.7.8.4.3 apply.

4.4.7.9 Connection of parts of *solid insulation* (cemented joints)

The *clearance* and *creepage distance* paths in the presence of a cemented joint between two insulating parts are determined as follows. An example is given in Figure D.9.

- Type 1 or type 2 protection as described in 4.4.7.8.4.3 applies.
- A cemented joint that is not evaluated as providing protection of type 1 or type 2 is neither considered *solid insulation* nor to reduce pollution degree. The *clearance* and *creepage distance*s of 4.4.7.4 and 4.4.7.5 apply for the pollution degree of the environment around the joint.

See 5.2.5.6 for preconditioning and test.

4.4.7.10 Requirements for electrical withstand capability

4.4.7.10.1 General

Where verification of *insulation* is impossible by *visual inspection* in 5.2.1 according to 5.2.2.1, test according to 4.4.7.10.2 or 4.4.7.10.3 applies between the considered circuits and for *solid insulation* on *components* and sub-assemblies.

4.4.7.10.2 *Basic insulation* or *supplementary insulation*

Basic insulation or supplementary insulation shall be tested as follows:

- *impulse withstand voltage* according to 5.2.3.2 or AC or DC voltage according to 5.2.3.3; and
- AC or DC voltage according to 5.2.3.4.

4.4.7.10.3 *Double insulation* or *reinforced insulation*

Double insulation or *reinforced insulation* shall be tested as follows:

- *impulse withstand voltage* according to 5.2.3.2 or AC or DC voltage according to 5.2.3.3; and
- AC or DC voltage according to 5.2.3.4;

For *solid insulation*, the partial discharge test according to 5.2.3.5 shall be performed in addition to the above tests, if

- the recurring peak *working voltage* across the *insulation* is greater than 750 V, and
- the voltage stress on the *insulation* is greater than 1 kV/mm.

The voltage stress is the working voltage (recurring peak) divided by the distance between two parts of different potential. See Figure D.14.

The partial discharge test shall be performed as a *type test* on all *components*, sub-assemblies and PWBs. In addition, a *sample test* shall be performed if the *insulation* consists of a single layer of material such as constructions that could be damaged due to partial discharge in air voids when exposed to voltage stress described above (e.g. cast resin, potting, moulding, triple insulated wire, etc.).

Double insulation shall be designed so that failure of the *basic insulation* or of the *supplementary insulation* will not result in reduction of the *insulation* capability of the remaining part of the *insulation*.

4.4.8 Compatibility with residual current-operated protective devices (RCD)

In addition to the *basic protection* and *fault protection* provided by *BDM/CDM/PDS,* some domestic and industrial *installations* provide RCD as additional protection against *insulation* faults.

NOTE 1 Circuit breaker incorporating residual current function (CBRs) according to IEC 60947-2:2016 and IEC 60947-2:2016/AMD1:2019, Annex B, and modular residual current device (MRCD) according to IEC 60947-2:2016 and IEC 60947-2:2016/AMD1:2019, Annex M, are equivalent to RCD.

NOTE 2 This requirement is not applicable in the USA and Canada.

An *insulation* fault or direct contact with certain types of *BDM/CDM/PDS* circuits can cause failure current with a DC component to flow in the *PE conductor* and thus reduce the ability of an RCD of type A or type AC (see IEC 60755) to provide this protection for other equipment in the *installation*.

To ensure the intended operation of an RCD provided by th*e installation, BDM/CDM/PDS* shall satisfy one of the following conditions a) or b).

a) Single-phase *BDM/CDM/PDS* that are *pluggable equipment type A* shall be designed so that, under normal operating and *single-fault conditions*, any resulting current with a smooth superimposed DC component of the current in the *PE conductor* does not exceed the DC current withstand requirements of 6 mA in IEC 60755 for RCD of type A or 10 mA for type F.
b) For *BDM/CDM/PDS* that are *pluggable equipment type B* or intended to be *permanently connected*, DC current in the *PE conductor* is not limited if the information and marking requirements of 6.3.9.5 are complied with.

In case of *PE conductor* currents with a smooth superimposed DC component exceeding the above values, suitable protective devices shall be selected and stated in the customer documentation, for example RCD type B or type F.

The *BDM/CDM/PDS* manufacturer shall provide information to ensure compatibility with RCD provided by the *installation.* It shall be checked by simulation or calculation of current in the *PE conductor* under normal and *single-fault conditions* according to the guideline provided in Annex H.

See 6.3.9.5 for information and marking requirements.

4.4.9 Capacitor discharge

For protection against electric shock hazard, capacitors within a *BDM/CDM/PDS* shall be discharged either to a voltage less than U_{DCL} of *DVC As*, or to a residual energy less than 0,5 mJ, after the removal of energy from the *PDS*.

a) For *BDM/CDM/PDS* of *pluggable equipment type A* and *pluggable equipment type B*, the discharge time shall not exceed 1 s or the *hazardous live parts* shall be protected against direct contact by at least IP2X (see 4.4.3.3).
b) For *permanently connected BDM/CDM/PDS*, the discharge time shall not exceed 5 s.
c) For pluggable and *permanently connected BDM/CDM/PDS* with a control *system* that prevents access to the capacitors, until discharged as described above, no discharge time is required.

For *BDM/CDM/PDS,* which do not meet the above requirements a), b) or c), access shall only be possible by means of a tool or key, and the information and marking requirements of 6.5.2 apply.

This requirement also applies to capacitors used for power factor correction, filtering, etc.

NOTE The requirements of 4.4.9 only consider the stored energy related to internal capacitors of the *BDM/CDM*. For the final application where the *BDM/CDM* is used as a *component*, and other sources of energy can be present, further considerations of stored charge can apply. See also 4.8 for multiple sources of supply.

Compliance is checked by test of 5.2.3.8.

See 6.5.2 for information and marking requirements.

4.4.10 Access conditions for high-voltage sections of *BDM/CDM/PDS* (*interlock*)

4.4.10.1 General

The high-voltage sections (transformer, converter, motor, etc.) shall be protected with respect to personnel safety.

- Personnel shall be prevented from accessing the high-voltage sections of a *BDM/CDM/PDS*. This protection is either provided by an appropriate *enclosure* according to IEC 60204-11:2018 with respect to personnel safety, or will be governed by the rules of the *installation* (example IEC 61936-1).
- If an *enclosure* is used, *interlocks* shall be used to prevent any access inside the *enclosure* of the high-voltage section when *mains supply* circuit breaker(s) providing the high-voltage to the circuit are on (see b) below). *Interlocks* are required on all *doors*. *Interlocks* are not required on *hinged panels* or *covers*.

  NOTE 1 Requirement is taken from UL 347A.

  NOTE 2 A *hinged panel* can be three bolted sides and a bolted, welded or similarly secured hinge.

a) Operating conditions

   Interlocking *doors* shall prevent any access inside the *enclosure* of the high-voltage converter section when *mains supply* circuit breaker(s) providing the high-voltage to the circuit are on, and if *hazardous live parts* have not been earthed – see b).

b) Access for maintenance – Earthing instructions

The earthing operation is performed after the normal discharge time stated by the *BDM/CDM/PDS* manufacturer. Care shall be taken to ensure that this operation is safe even in case of failure of the discharge circuit. Care shall also be taken that, on the input and output side of the *BDM/CDM/PDS*, the stray capacitance of cables, motor and/or transformer shall be discharged before possible access to *live parts*. The requirements of 4.4.9 apply.

Earthing devices (earthing switches and/or earthing cables) shall be provided in sufficient quantity to facilitate work being carried out in safety on the *live parts* of the high-voltage equipment of the *PDS*. The earthing devices shall comply with the relevant requirements of IEC 62271-102:2018 or IEC 61230:2008. The earthing contacts, or an indication that the contacts of the switches are closed, shall be visible by the maintenance personnel before they access the equipment.

NOTE 3 In particular cases, (for example, load-commutated inverters), two earthing devices (one supply side, one load side) can be required.

For parts which are not directly earthed by an earthing switch, the *component* manufacturers shall provide safe instructions to perform earthing.

For test, see 5.2.2.8

For marking, see 6.3.9.6 and 6.5.7.

4.4.10.2 Isolating means for *high-voltage BDM/CDM/PDS*

4.4.10.2.1 *BDM/CDM/PDS* with isolating means

4.4.10.2.1.1 General

The isolating means shall be an externally-operable, gang-operated power circuit isolating means with position indication that complies with 4.4.10.2.1.1 to 4.4.10.2.1.5.

For test, see 5.2.2.8.

The following are examples of possible isolating means:

a) three-pole isolating switch;
b) three-pole isolating switch in mechanical combination with high-voltage motor circuit fuses;
c) three-pole load break switch;
d) draw out three-pole contactor (with or without fuse assembly);
e) draw out three pole circuit breaker.

4.4.10.2.1.2 Operating location

The isolating mechanism indicated in 4.4.10.2.1.1 shall be arranged to be operated from a location where the operator is not exposed to energized parts and shall be arranged to open all ungrounded conductors of the circuit simultaneously with one operation. When a disconnecting means disconnects a permanent *PE conductor*, it shall open all energized conductors and the *PE conductor* in the same operation.

4.4.10.2.1.3 Visibility of isolating gap

The isolating means shall provide visible indication of an isolating gap in the circuit.

The isolation gap or a mechanically operated indicator shall be visible through a window. The mechanical operator shall be actuated by the movement of the actual isolating switch assembly, the shutter of a draw-out assembly, etc. The action of the mechanical indicator shall not be dependent on the movement of the operating handle or mechanism alone.

4.4.10.2.1.4 Interlocking and locking

The high-voltage isolating means shall be interlocked as indicated in 4.4.10.1.

The high-voltage isolating means shall have provision for being locked by mechancial means in the open position.

4.4.10.2.1.5 De-energisation of switch blades

All load side switch blades shall be de-energized when the switch is in the open position, except switches that are intended to be energized from both sides (for example, bus tie, loop sectionalizing). These switches shall not have energized blades in the open position unless

a) barriers or *enclosure*s are installed over the switches for protection against contact with the energized switch blades, and
b) the switch is marked in accordance with 6.5.7.

4.4.10.2.2 *BDM/CDM/PDS* without isolating means

BDM/CDM/PDS that is not provided with the isolating means noted in 4.4.10.2.1 shall comply with a) and b) below:

a) the *BDM/CDM/PDS* shall be marked in accordance with 6.5.7;
b) instructions shall be provided with respect to external isolating means and interlocking in accordance with 6.5.7.

4.5 Protection against electrical energy hazards

4.5.1 General

Subclause 4.5 provides requirements to address protection against electrical energy hazards. These hazards are not associated with electric shock in 4.4, fire hazards in 4.6 or burns in 4.6.5.

Examples are heat, pressure explosion, chemical expulsion, etc.

Failure of any *component* within the *BDM/CDM/PDS* shall not release sufficient energy to lead to a hazard.

Where appropriate, the possibility shall be considered of energy transfer from the motor to the *BDM/CDM* when the driven equipment over-runs the *BDM/CDM* control.

A risk of injury due to an electrical energy hazard exists if there is a hazardous electrical energy between two or more uninsulated *live part*s (one of which may be earthed) that can be bridged, when tested with the jointed test finger according to Figure M.2, in any articulated position.

BDM/CDM/PDS shall be designed so that there is no risk of electrical energy hazard from accessible circuits by

- limiting the energy according to 4.5.3, or
- providing *enclosures*, barriers, guards, and similar means according to 4.4.3.3.1, which can only be removed with the use of a tool or key.

Compliance is checked by the non-accessibility test of 5.2.2.2.

4.5.2 Determination of hazardous electrical energy level

4.5.2.1 General

A hazardous electrical energy level is considered to exist if the voltage is 2 V or more and one or both of the following applies:

a) the power available exceeds the limit of limited power sources in 4.5.3;

b) the stored energy exceeds 20 J.

Compliance of the available power shall be checked by 5.2.3.9 and the stored energy shall be checked by calculation as follows:

$$E \leq 0{,}5 \times CU^2$$

where

E is the stored energy, in joules (J);

C is the capacitance, in farads (F);

U is the measured voltage on the capacitor, in volts (V).

4.5.2.2 Stored electrical energy

Capacitors within a *BDM/CDM/PDS* shall be discharged to an energy level less than given in 4.5.2.1 b), within 5 s after the removal of supply voltage from the *PDS*. If this requirement is not achievable for functional or other reasons, the information and marking requirements of 6.5.2 apply.

Compliance is checked by *visual inspection* in 5.2.1 of the *BDM/CDM/PDS* and relevant circuit diagrams, taking into account the possibility of disconnection with any "ON"/"OFF" switch in either position and non-operation of periodic power consuming devices or *components* within the *PDS*. If the capacitor discharge time cannot be accurately calculated, the discharge time shall be measured according to 5.2.3.8.

4.5.3 Limited power sources

Limited power sources can be used to minimize risk of fire and risk of energy. A limited power source shall comply with one of the following requirements:

a) the output is inherently limited in compliance with Table 15;

b) a linear or non-linear impedance limits the output in compliance with Table 15. If a positive temperature coefficient device (e.g. PTC) is used, it shall pass the applicable tests specified in IEC 60730-1:2013, IEC 60730-1:2013/AMD1:2015 and IEC 60730-1:2013/AMD2:2020;

c) a regulating network limits the output in compliance with Table 15 both with and without a *single-fault condition* in the regulating network;

d) an *overcurrent* protective device is used and the output is limited in compliance with Table 16.

If the limited power source depends on *overcurrent* protective device(s), the current rating of at least one of the protective device(s) in the current path shall not exceed the limit in Table 16 and it shall be a fuse or a non-adjustable, non-autoreset, electromechanical device.

A limited power source operated from an AC *mains supply*, or a battery-operated limited power source that is recharged from an AC *mains supply* while supplying the load, shall incorporate an isolating transformer.

Compliance to determine the maximum available power is checked by test of 5.2.3.9.

Table 15 – Limits for power sources without an *overcurrent* protective device

Output voltage[a] U_{oc}		Output current [b d] I_{sc}	Apparent power [c d] S
V AC RMS	V DC	A	VA
≤ 30	≤ 30	≤ 8	≤ 100
-	30 < U_{oc} ≤ 60	≤ 150 / U_{oc}	≤ 100

[a] U_{oc}: Output voltage measured in accordance with 5.1.5.3 with all load circuits disconnected. Voltages are for substantially sinusoidal AC and ripple-free DC. For non-sinusoidal AC and DC with ripple greater than 10 % of the peak, the peak voltage shall not exceed 42,4 V.

[b] I_{sc}: Maximum output current with any non-capacitive load, including a short-circuit.

[c] S (VA): Maximum output apparent power in VA with any non-capacitive load.

[d] Measurement of I_{sc} and S are made 5 s after application of the load if protection is by an electronic circuit or a positive temperature coefficient device (e.g. PTC), and 60 s in other cases.

Table 16 – Limits for power sources with an *overcurrent* protective device

Output voltage[a] U_{oc}		Output current [b d] I_{sc}	Apparent power [c d] S	Current rating of *overcurrent* protective device [e]
V AC RMS	V DC	A	VA	A
≤ 20	≤ 20	≤ 1 000/U_{oc}	≤ 250	≤ 5,0
20 < U_{oc} ≤ 30	20 < U_{oc} ≤ 30			≤ 100/U_{oc}
–	30 < U_{oc} ≤ 60			≤ 100/U_{oc}

[a] U_{oc}: Output voltage measured in accordance with 5.1.5.3 with all load circuits disconnected. Voltages are for substantially sinusoidal AC and ripple free DC. For non-sinusoidal AC and for DC with ripple greater than 10 % of the peak, the peak voltage shall not exceed 42,4 V.

[b] I_{sc}: Maximum output current with any non-capacitive load, including a short-circuit, measured 60 s after application of the load.

[c] S (VA): Maximum output VA with any non-capacitive load measured 60 s after application of the load.

[d] Current limiting impedances remain in the circuit during measurement, but *overcurrent* protective devices are bypassed. The reason for making measurements with *overcurrent* protective devices bypassed is to determine the amount of energy that is available to cause possible overheating during the operating time of the *overcurrent* protective devices.

[e] Current ratings of *overcurrent* protective devices that break the circuit within 120 s with a current equal to 210 % of the current rating specified in the table.

The test according to 5.2.3.9 can be omitted if *overcurrent* protective devices are used that comply with

- IEC 60127-2:2014, Sheet 3, 4, 6, or 8, or
- IEC 60127-4.

NOTE In the USA and Canada, the used overcurrent devices must comply with:

- UL 248-14/CSA C22.2 No.248.14, or
- UL 248-14/CSA C22.2 No.248.14 microfuses

Fuses that comply with the above-mentioned *component* standards will limit the maximum current and maximum apparent power to values below the limits in Table 16 in less than 60 s, based on the maximum opening and pre-arcing times specified in the applicable *component* standards.

4.6 Protection against fire and thermal hazards

4.6.1 General

The protection against fire and thermal hazards under normal operating conditions, *abnormal operating conditions* and *single-fault conditions* are essential for the safety of the *BDM/CDM/PDS* and include the following items:

- circuit analysis of *abnormal operating condition* and *single-fault conditions* according to 4.2 considering
  - output short-circuit tests according to 5.2.4.5,
  - electronic motor overload tests according to 5.2.4.6,
  - output overload test according to 5.2.4.9,
  - breakdown of *component* tests according to 5.2.4.10,
  - *insulation* coordination for *functional insulation* on PWB and *components* according to 4.4.7.3, 4.4.7.4, 4.4.7.5 and 4.4.7.7, and
  - use of fire-retardant polymeric materials for *enclosure* and *components* part of the *enclosure* according to 4.6.4.2;
- normal operating conditions considering limits on *components* and material temperatures according to 4.6.5.

NOTE In general, it is considered that a *fire enclosure* is not applicable for industrial *BDM/CDM/PDS* built into another application where they are covered by an OEM standard (e.g. IEC 60204-1 and IEC 61439-1).

When these measures are insufficient to ensure sufficient fire mitigation, the requirements for fire-retardant materials, *components* and material temperatures, and further measures for mitigation of fire are covered by 4.6.2 to 4.6.4.4.

4.6.2 Circuits and *components* representing a fire hazard

The following types of circuits and *components* shall be considered as a potential fire hazard:

- circuits directly connected to the *mains supply*;
- circuits that are directly connected to the *non-mains supply* but exceed the limits for limited power sources in 4.5.3;
- *components* having unenclosed arcing parts.

Appropriate risk mitigation according to 4.6.3 and 4.6.4 may be applicable for *BDM/CDM/PDS*.

For *components* within a circuit not representing a fire hazard, 4.6.2 does not apply.

4.6.3 Selection of *components* to mitigate the risk of a fire hazard

The risk of ignition due to high temperature shall be minimized by the appropriate selection and use of *components* and by suitable construction.

Electrical *components* shall be used in such a way that their maximum working temperature under normal operating conditions, *abnormal operating condition*s and *single-fault conditions* is less than that necessary to cause ignition of the *components* and the surrounding materials.

Under normal operating conditions, the limits in Table 17 shall not be exceeded for *components* or their surrounding material.

Where it is not practical to protect *components* against overheating under *abnormal operating conditions* and *single-fault conditions*, all materials in contact with such *components* shall be of flammability class V-1 or better according to IEC 60695-11-10:2013.

Compliance shall be confirmed by *visual inspection* in 5.2.1 of *components* and material data sheets and, where necessary, by test.

4.6.4 Fire protection provided by *enclosure*s

4.6.4.1 General

The mitigation of fire hazard shall be achieved by meeting the requirement in 4.6.4.2 and one of the following measures a) or b):

a) the *open type BDM/CDM* is intended to be built into an additional *enclosure* or *restricted-access area* which provides the protection of mitigation of fire according to 4.6.4.3;
b) the *BDM/CDM* is designed with an *enclosure* which provides mitigation of fire according to 4.6.4.4.

4.6.4.2 General *enclosure* requirement

Materials used for *enclosure*s shall meet the test requirements of 5.2.5.5.

Metals, ceramic materials, and glass which is heat-resistant tempered, wired or laminated, are considered to comply without test.

Non-metallic, non-ceramic, and non-glass materials are considered to comply without test if, in the minimum thickness used, the material is of flammability class 5VA, according to IEC 60695-11-20:2015.

Components which fill an opening in an *enclosure*, and which are intended to be mounted in this way, need not be evaluated for compliance with the flammability requirements of 5.2.5.5, provided that the *components* comply with the flammability aspects of the relevant *component* standard. See also 4.13.

EXAMPLE Fuse-holders, switches, pilot lights, connectors and appliance inlets.

Compliance is checked by *visual inspection* in 5.2.1 and, where necessary, by test.

The *BDM/CDM/PDS* manufacturer may employ data from the *components* or *enclosure* material supplier to demonstrate compliance with the above requirements. In this case, no further testing is required.

4.6.4.3 *Open type BDM/CDM* intended to be installed in additional *enclosure* or *restricted-access area*

Open type BDM/CDM does not need to provide protection against the spread of fire.

For marking, see 6.3.6.1.

NOTE When protection against mitigation of fire hazard is provided by an additional *enclosure* in the final application, the mitigation of fire is assumed to be covered by the standard covering this application (e.g. IEC 61439-1, IEC 60204-1).

4.6.4.4 *BDM/CDM* designed to mitigate fire hazard by means of the *enclosure*

The following applies:

- the *BDM/CDM* is built into *fire enclosure* meeting the general *enclosure* requirements in 4.6.4.2;
- the *BDM/CDM* is built into *fire enclosure* meeting the requirement for *fire enclosure* according to IEC 62477-1:2022, 4.6.3;

- openings shall be less than 2,5 mm in minor dimension unless a risk analysis according to 4.2 can prove that the construction provides adequate protection for the mitigation of fire hazard.

4.6.5 Temperature limits

4.6.5.1 General

Internal parts and external enclosure parts of the *BDM/CDM/PDS* shall not attain temperatures which can lead to a risk of fire, burn or electric shock due to high temperatures when operated under normal operating conditions and maximum ratings as determined by 5.2.3.10.

Other rated operating conditions such as duty cycle operation, thermal derating, operation in altitude above 1 000 m, temporary overcurrent conditions and cooling control characteristic shall be tested or calculated.

Compliance is checked by test of 5.2.3.10.

For marking, see 6.3.3 and 6.2.1.4.

4.6.5.2 Internal parts

BDM/CDM and its *component* parts shall not exceed the temperature limits in Table 17 when tested in accordance with the ratings of the *BDM/CDM* as specified according to 4.9.

Table 17 – Maximum measured temperatures for internal materials and *components*

	Materials and *components*	**Thermocouple method** °C	**Electrical resistance method** °C
1	Rubber- or thermoplastic-insulated conductors [a]	75	--
2	Field wiring terminals and other parts that may contact the *insulation* of field wiring [b]	[b]	--
3	Copper bus bars and connecting straps	[c]	--
4	*Insulation systems* on magnetic *components* [d]		
	Class A (105)	105	125
	Class E (120)	120	135
	Class B (130)	125	145
	Class F (155)	135	155
	Class H (180)	155	175
	Class N (200)	175	195
	Class R (220)	195	215
5	Phenolic composition [a]	165	--
6	On bare resistor material	415	--
7	Capacitor	[f]	--
8	Power electronic devices	[g]	--
9	PWBs	[h]	--
10	*Components* bridging at least *basic protection*	[f]	--
11	Liquid cooling medium	[i]	--

NOTE In the USA, field wiring terminals must be marked only for 60 °C, 75 °C, or 60 °C to 75 °C wire and must not exceed more than 15 °C temperature rise above the lowest *insulation* temperature rating, except for terminals marked AL&Cu, which must not exceed 75 °C.

[a] The limitation on phenolic composition and on rubber and thermoplastic *insulation* does not apply to compounds which have been investigated and found to meet the requirements for a higher temperature.

[b] The maximum terminal temperature should not exceed the temperature rating of the terminal and the *insulation* temperature rating of the conductor or cable specified by the manufacturer (see 6.3.7.4.2 c)).

[c] The maximum permitted temperature is determined by the temperature limit of support materials or *insulation* of connecting wires or other *components*. A maximum temperature of 140 °C is recommended.

[d] The maximum temperatures on *insulation* of magnetic *components* assume thermocouples are applied on the surface of coils, and are therefore not located on hot-spots. The electrical resistance method results in a measurement of the average temperature of the winding.

[e] Not used in this table.

[f] For a *component*, the maximum temperature specified by the manufacturer should not be exceeded.

[g] The maximum temperature on the case should be the maximum case temperature for the applied power dissipation specified by the manufacturer of power electronic devices.

[h] The maximum operating temperature of the PWB shall not be exceeded.

[i] The maximum temperature of the cooling medium, specified by the manufacturer of the medium or determined from the known characteristics of the medium, should not be exceeded.

The electrical resistance method for temperature measurement as specified in Table 17 consists of the calculation of the temperature rise of a winding using the following formula:

$$\Delta t = \frac{r2}{r1}(k + t1) - (k + t2)$$

where

Δt is the temperature rise;

r_1 is the resistance at the beginning of the test (ohms);

r_2 is the resistance at the end of the test (ohms);

t_1 is the *ambient temperature* at the beginning of the test (ºC);

t_2 is the *ambient temperature* at the end of the test (ºC);

k is 234,5 °C for copper, 225,0 °C for electrical conductor grade (EC) aluminium; values of the constant for other conductors shall be determined.

NOTE The constant k is the negative of the temperature at which the resistance of the metal would be zero if it decreased linearly.

The temperature limits of Table 17 shall be compared to the temperature rise shifted by the maximum *ambient temperature* of the *BDM/CDM/PDS*.

4.6.5.3 *Accessible part*s of *BDM/CDM/PDS*

The maximum temperature shall be in compliance with Table 18 to prevent

- burns during touch of *accessible part*s of *BDM/CDM/PDS*,
- burns during operating the *BDM/CDM/PDS*, and
- long-term degradation of building materials when in contact with the *BDM/CDM/PDS.*

It is permitted that *accessible part*s that are required to get hot as part of their intended function (for example heatsinks) may have temperatures up to 150 °C, if the parts are not in contact with building materials, and are marked with the warning given in 6.4.4.

For *BDM/CDM/PDS* only intended for use in a *restricted-access area* or *open type BDM/CDM*, the temperature of *accessible part*s may exceed 150 °C and shall be marked per 6.4.4.

When the temperature on the surface of *BDM/CDM/PDS* exceeds the limit in Table 18 for the mounting surface when operated under normal operating conditions, the construction shall be such that

a) the mounting surface shall not attain a temperature higher than the specified limit in Table 18 during the temperature test, or
b) the installation manual shall contain a warning to install the *BDM/CDM/PDS* to non-combustible material. For marking, see 6.3.5.

Table 18 – Maximum measured temperatures for *accessible part*s of *BDM/CDM/PDS*

Part	**Limits °C**					
	(Coated) metal [a]				**Glass, porcelain and vitreous material**	**Plastic and rubber**
	1	**2**	**3**	**4**		
User operated devices (knobs, handles, switches, displays, etc.) which are held continuously during normal and *single-fault condition* (approx. 10 s)	55	55	55	60	65	70
User operated devices (knobs, handles, switches, displays, etc.) which are held for short periods only, during normal and *single-fault condition* (approx. 1 s)	60	70	65	85	75	80
Accessible *enclosure* parts likely to be touched (approx. 1 s)	65	75	70	90	80	85
Mounting surface	90					

NOTE 1 In Table 18, the values for *accessible part*s are taken from IEC Guide 117 (burn threshold). For short-duration contact with user operated devices, the values were reduced by 5 °C to allow for some margin. IEC Guide 117 also provides values for burn thresholds for other coatings or materials.

NOTE 2 The main figures of IEC Guide 117 are reproduced in Annex J for information.

[a] Coating of metal surfaces:

1: none (bare metal)

2: lacquer or varnish (minimum 50 µm)

3: porcelain enamel (minimum 160 µm) / powder painted surface (minimum 60 µm)

4: polyamide 11 or 12 (minimum 400 µm)

4.7 Protection against mechanical hazards

4.7.1 General

Failure of any *component* within the *BDM/CDM/PDS* shall not release sufficient energy to lead to a hazard, for example, expulsion of material into an area occupied by personnel.

Mechanical failure due to critical speed considerations or torsional problems can create a hazard to operating personnel. These considerations are applicable to all *BDM/CDM/PDS*, although they are increasingly significant with increased *BDM/CDM/PDS* size, such as with *high-voltage BDM/CDM/PDS*. As these subjects are application-dependent, it is not possible to include specific requirements in this document.

4.7.2 Critical torsional speed

Where appropriate, communication should be established between *BDM/CDM/PDS* manufacturer, driven equipment manufacturer, installer, and user with respect to any anticipated critical torsional speed considerations (e.g. where mechanical resonance may occur).

For marking, see 6.3.10.3.

4.7.3 Transient torque analysis

Transient torque analysis is an important design tool to check torsional stresses in the whole mechanical string of the *PDS*. For example, the following operating conditions are areas of concern:

- start-up;
- single-phase or three-phase short-circuit at the terminals of an AC motor;
- impact of possible commutation failure of an AC *BDM/CDM*;
- impact of the harmonic torque *component*s of an AC *BDM/CDM*;
- short-circuit at the armature terminals of a DC motor;
- field supply loss in a DC *BDM/CDM* or DC motor.

A *BDM/CDM/PDS* shall not incorporate an *overcurrent protective device* in a motor field supply circuit, unless the *BDM/CDM/PDS* incorporates a detector that senses loss of field current or field voltage and prevents overspeed caused by field loss.

Where appropriate, communication should be established with the driven equipment supplier and the information required by 6.3.10.4 provided.

4.7.4 Specific requirements for liquid cooled *BDM/CDM/PDS*

4.7.4.1 General

When applicable, *BDM/CDM/PDS* and its cooling *system*, which uses liquid coolant to remove heat, shall comply with the requirement of 4.7.4.3.2 to 4.7.4.3.8.

Sealed heat-pipe cooling *systems*, used to transfer heat from a hot *component* to a heat sink, are not considered to be liquid cooling *systems* in this document. However, the possible failure of such *components* shall be considered during the circuit analysis of 4.2.

4.7.4.2 Coolant

The specified coolant (see 6.2) shall be suitable for the anticipated *ambient temperature*s during storage and operation. Coolant temperature in operation shall not exceed the limit specified in Table 17 and the environmental stresses of 4.9.

The coolant used in a cooling *system* shall be a refrigerant investigated for this purpose (e.g. water, de-ionized water, glycol, non flammable synthetic oils or any combination of these).

Compliance is checked by *visual inspection* in 5.2.1 of *components* and material data sheets and test of 5.2.3.10.

NOTE Flammable coolants used in cooling *systems* are not covered by this document.

4.7.4.3 Design requirements

4.7.4.3.1 General

The liquid containment *system components* shall be compatible with the liquid to be used.

BDM/CDM/PDS using liquids shall be constructed so that it is unlikely that either a dangerous concentration of these materials or a hazard in the meaning of this document will be created by condensation, vaporization, leakage, spillage or corrosion during normal operating conditions, storage, filling or emptying.

Compliance is checked by *visual inspection* in 5.2.1 of *components* and material data sheets.

4.7.4.3.2 Corrosion resistance

All cooling *system components* shall be suitable for use with the specified coolant. They shall be corrosion resistant and shall not corrode as a result of prolonged exposure to the coolant and/or air.

Compliance is checked by *visual inspection* in 5.2.1 of *components* and material data sheets.

4.7.4.3.3 Tubing, joints and seals

Cooling *system* tubing, joints and seals shall be designed to prevent leakage during excursions of pressure over the *expected lifetime* of the *BDM/CDM/PDS*. The entire cooling *system* including tubing shall satisfy the requirements of the hydrostatic pressure test of 5.2.7.

Protected tubing as well as unprotected tubing used to connect refrigerant-containing *components* shall comply with the minimum wall thickness requirements of Table 19.

Table 19 – Minimum tubing wall thickness

Outside diameter		**Minimum wall thickness** [a] mm (inch)					
		Copper				**Steel**	
mm	(inch)	**Protected**		**Unprotected**			
6,35	(1/4)	0,62	(0,024 5)	0,67	(0,026 5)	0,64	(0,025)
7,94	(5/16)	0,62	(0,024 5)	0,72	(0,028 5)	0,64	(0,025)
9,53	(3/8)	0,62	(0,024 5)	0,72	(0,028 5)	0,64	(0,025)
12,70	(1/2)	0,62	(0,024 5)	0,72	(0,028 5)	0,64	(0,025)
15,88	(5/8)	0,80	(0,031 5)	0,80	(0,031 5)	0,81	(0,025)
19,05	(3/4)	0,80	(0,031 5)	0,98	(0,038 5)	0,81	(0,032)
22,23	(7/8)	1,04	(0,041 0)	1,04	(0,041 0)	1,17	(0,032)
25,40	(1)	1,17	(0,046 0)	1,17	(0,046 0)	1,17	(0,046)
28,58	(1-1/8)	1,17	(0,046 0)	1,17	(0,046 0)	1,17	(0,046)
31,75	(1-1/4)	1,28	(0,050 5)	1,28	(0,050 5)	1,17	(0,046)
34,93	(1-3/8)	1,28	(0,050 5)	1,28	(0,050 5)	1,58	(0,046)
38,10	(1-1/2)	1,41	(0,055 5)	1,41	(0,055 5)	1,58	(0,062)
41,3	(1-5/8)	1,410	(0,055 5)	1,410	(0,055 5)	–	(0,062)
54,0	(2-1/8)	1,626	(0,064 0)	1,626	(0,064 0)	–	–
66,7	(2-5/8)	1,880	(0,074 0)	1,880	(0,074 0)	–	–

NOTE "Protected" implies that the tubing is shielded by the cabinet or assembly, to the extent that unintended damage caused by objects such as tools falling on or otherwise striking the tubing during handling and after installation of the unit is prevented.

This protection can be provided in the form of baffles, channels, flanges, perforated metal, or equivalent means. If a cabinet is employed for the intended *installation* of a unit, the tubing is considered shielded. Tubing not so shielded is considered to be unprotected.

[a] Nominal wall thickness of tubing will have to be greater than the thickness indicated to maintain the minimum wall thickness.

4.7.4.3.4 Provision for condensation

Where internal condensation occurs during normal operating conditions or maintenance, measures shall be taken to prevent degradation of *insulation*. See 4.12.8.

4.7.4.3.5 Conductivity of coolant

When the coolant is intentionally in contact with *live parts* (for example non-earthed heatsinks), the conductivity of the coolant shall be continuously monitored and controlled, in order to avoid hazardous current flow through the coolant.

4.7.4.3.6 Leakage of coolant

Measures shall be taken to prevent leakage of coolant onto *live parts* as a result of normal operating conditions, servicing, or loosening or detachment of hoses or other cooling *system* parts during the *expected lifetime*.

If a pressure relief mechanism is provided, this shall be located so that there shall be no leakage of coolant onto *live parts* when it is activated.

Wetting of *live parts* or *electrical insulation* shall be prevented during a leakage of coolant.

Compliance is checked by visual inspection in 5.2.1.

4.7.4.3.7 Loss of coolant

Loss of coolant from the cooling *system* shall not result in thermal hazards, explosion, or electric shock hazard. The requirements of the loss of coolant test of 5.2.4.13.4 shall be satisfied.

4.7.4.3.8 *Insulation* requirements for coolant hoses

When the coolant is intentionally in contact with *live part*s (for example non-earthed heatsinks), the coolant hoses shall be considered as a part of the *insulation system*. Depending on the location of the hoses, they shall comply with applicable requirements of 4.4.7 for *functional insulation, basic insulation, supplementary insulation* or *enhanced insulation.*

4.7.5 Mechanical hazards from rotating parts

4.7.5.1 General

Rotating parts shall not cause hazards.

4.7.5.2 Mechanical hazards caused by fan

Fans and their blades shall not cause injury under normal operating conditions, and during service and maintenance. For more information, see IEC 62368-1:2018, 8.2.

NOTE 1 For protection against pain, see IEC 62368-1.

NOTE 2 The term "injury" means that a doctor or hospital emergency attention can be needed.

Hazardous fan blades shall be protected by an *enclosure* or barriers fulfilling IPXXB. See test in 5.2.2.2.

No protection is required for fan blades when it can be verified by the formulas below that no injury will occur when touched:

- plastic fan blades complying with $\frac{N}{44\,000}+\frac{K}{7\,200}\leq 1$;
- other fan blades complying with $\frac{N}{22\,000}+\frac{K}{3\,600}\leq 1$.

The K factor is determined from the formula:

$$K = 6 \times 10^{-7} \times m \times r^2 \times N^2$$

where

m is the mass (kg) of the moving part of the fan assembly (blade, shaft and rotor);

r is the radius (mm) of the fan blade from the centre line of the motor (shaft) to the tip of the outer area likely to be touched,

N is the rotational speed (r/min) of the fan blade. The fan maximum speed in the application shall be taken into account.

4.7.5.3 Expelled parts

All moving parts shall be properly secured and protected in compliance with requirements of 4.2.

Examples include

- protection by *enclosure*, barrier or guarding, and
- usage of common mechanical practices such as lock washers, self-retaining hardware, proper torqueing of hardware, rivets, welding, etc.

Compliance is checked by visual inspection according to 5.2.1.

4.7.6 Sharp edges

Edges, projections, corners, openings, guards, handles and the like that are accessible to the operator shall be smooth and rounded so as not to cause injury during installation, normal operating conditions and maintenance of the equipment.

Conformity is checked by *visual inspection type test* in 5.2.1 and, if necessary, by application of an object that represents a finger in size, shape and hardness, to check for abrasions or cuts.

NOTE An acceptable procedure is described in IEC TR 62854:2014 or UL 1439.

4.8 *BDM/CDM/PDS* with multiple sources of supply

4.8.1 General

If *BDM/CDM/PDS* is provided with more than one supply *port* (for example, with different voltages or frequencies or as backup power), the design shall be such that all of the following conditions a), b) and c) are met:

a) separate means of connection are provided for each *port*;

b) supply plug connections, if any, are not interchangeable if a hazard could be created by incorrect plugging;

c) hazards, within the meaning of this document, shall not be present under normal operating conditions or *single-fault conditions* due to the presence of multiple sources of supply. Actions such as connection and disconnection or energizing and de-energizing of a supply are considered a normal operating condition.

See also 4.4.7.1.7.

Compliance is checked by the evaluation of 4.2.

For marking, see 6.5.5.

The following are examples of the types of hazards to be considered.

1) Backfeeding – the presence of voltage or energy fed back to any of the input terminals of the *BDM/CDM/PDS* from of its sources, either directly or by a leakage path, including regenerative mode.
2) Unintentional islanding – when the *BDM/CDM/PDS* continues to provide output power when input power is removed from the input power *port*s.
3) *Touch current* levels may be higher with multiple sources connected simultaneously (if that is a normal operating condition for the *BDM/CDM/PDS*).
4) Hazard resulting from damage to one or more connected sources (for example, a generator) due to energy from another source, for example the *mains supply*.
5) Damage to wiring due to currents higher than the wiring is designed for flowing from another source.

4.8.2 *Low-voltage* DC link sharing

4.8.2 defines additional specific requirement when two or more *BDM/CDM* of voltage source type share their internal DC voltage source.

If two or more *BDM/CDM* of a *PDS* are intended to be installed within the same *enclosure* or forming the same *enclosure*, a *PDS* circuit analysis of the effect of *component* failure shall be performed according to 4.2 and test shall be conducted accordingly for the complete assembly.

If two or more *BDM/CDM* of a *PDS* are intended to be installed in separate *enclosure*s, each DC power *port* connected to the DC link shall be protected against external *overcurrent*. A *PDS* circuit analysis of the effect of *component* failure shall be performed according to 4.2 for each *BDM/CDM* and test shall be conducted accordingly.

NOTE Earth fault current protection of the DC link is typically provided by the DC distribution *system*.

4.9 Protection against environmental stresses

4.9.1 General

The *BDM/CDM/PDS* shall not present any hazards as a result of specified environmental stresses for which the equipment is marked. Based on guidance in IEC 60721-3-0:1984 and IEC 60721-3-0:1984/AMD1:1987[2], as a minimum, the *BDM/CDM/PDS* shall satisfy the environmental requirements in Table 20 and shall demonstrate this with environmental tests of 5.2.6.

NOTE 1 The test requirements of 5.2.6 are based on guidance in IEC TR 60721-4-3:2001, IEC TR 60721-4-3:2001/AMD1:2003, and IEC TR 60721-4-4:2001, IEC TR 60721-4-4:2001/AMD1:2003.

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2 This publication has been withdrawn.

More demanding requirements than in Table 20 may be specified by the manufacturer; in this case, the less demanding tests of this document shall be replaced with a more severe testing required for the higher level.

NOTE 2 An example of a more demanding requirement could be an indoor corrosive environment.

The manufacturer shall specify the following service conditions for operation, storage and transportation, as applicable:

- coolant temperature (min./max.);
- *ambient temperature* (min./max.);
- humidity (min./max.);
- pollution degree;
- vibration;
- altitude for thermal consideration, if rated for operation above 1 000 m;
- altitude for *insulation* coordination considerations, if rated for operation above 2 000 m (maximum).

NOTE 3 Environmental categories as specified in IEC 60721 (all parts) can be used where appropriate.

The manufacturer shall state the environmental service condition for the *BDM/CDM/PDS* according to Table 20.

For marking, see 6.3.3 and 6.3.6.3.

NOTE 4 In the USA and Canada, the environmental temperature addressed is 0°C to 40 °C, unless otherwise stated.

Table 20 – Environmental service conditions

Condition	Indoor unconditioned	Outdoor unconditioned
Standard	IEC 60721-3-3:1994, IEC 60721-3-3:1994/AMD1:1995 and IEC 60721-3-3:1994/AMD2:1996[3]	IEC 60721-3-4:2019
Climatic	Class 3K3	Class 4K6
Low temperature	+5 °C	–20 °C
High temperature	40 °C	55 °C
Low humidity	5 % R.H.	4 % R.H.
High humidity	85 % R.H.	100 % R.H.
condensing	Not permitted	Permitted
Pollution degree	3 [b]	4 [c]
Humidity skin condition [d]	Water wet [a]	Salt water wet [a]
Chemically active substances	Class 3C1 (no salt mist)	Class 4C2 (salt mist) [a]
Mechanically active substances	Class 3S1 (no requirement)	Class 4S2 (dust and sand)
Mechanical	Class 3M1 (vibration: 1 m/s^2)	Class 4M1 (vibration: 1 m/s^2)

[3] This document and the annexes has been withdrawn.

Condition	Indoor unconditioned	Outdoor unconditioned
Biological	Class 3B1 (no requirement)	Class 4B2 (mould/fungus/rodents/termites)
UV resistance	No requirement	4.12.9

[a] Where it is ensured that the equipment will not be used in water wet or salt water wet condition, the manufacturer may choose to rate the equipment for a less severe condition. In this case, the rating shall be indicated in the documentation, according to 6.3.3 and 6.2.1.4.

[b] Pollution degree 2 may be provided if the conditions in 4.4.7.1.3 are satisfied.

[c] Pollution degree 2 or 3 may be provided if the *enclosure* provides sufficient protection against conductive pollution and the conditions in 4.4.7.1.3 are satisfied.

[d] This requirement is added to this table due to interacting of users and *BDM/CDM/PDS* when selecting the applicable *DVC As*. For example, the dry skin of the hand becomes wet when touching a wet *BDM/CDM/PDS*.

For use in outdoor unconditioned environment, where internal condensation cannot be excluded, one or more of the following a), b) or c) is required:

a) measures shall be provided in the *BDM/CDM/PDS* to prevent energizing or operation during condensation;
b) the damp heat test (cyclic) shall be performed, see 5.2.6.3.5;
c) marking is required to specify heating, see 6.3.3 d).

Compliance is checked by test of 5.2.6.

4.9.2 Protection against corrosion

Iron and steel parts shall be protected against corrosion by enameling, galvanizing, plating, or other equivalent means. This does not apply to the following items:

1) parts where such protection is impracticable;
2) parts, where the effects of corrosion will not result in a risk of fire, electric shock, or injury to persons.

4.10 Protection against excessive acoustic noise hazards

4.10.1 General

The *BDM/CDM/PDS* shall provide protection against excessive acoustic noise. Compliance tests are carried out if the *BDM/CDM/PDS* is likely to cause such hazards.

4.10.2 Acoustic noise level

If *BDM/CDM/PDS* produces noise at a level which could cause a hazard, the noise shall be measured to determine the maximum noise level which the *BDM/CDM/PDS* can produce (sounds from alarms are not included). If the measured acoustic pressure exceeds 70 dBA, the manufacturer shall provide information against the effects of acoustic noise.

Compliance is checked by test of 5.2.2.9.

For marking, see 6.4.1 e).

4.11 Wiring and connections

4.11.1 General

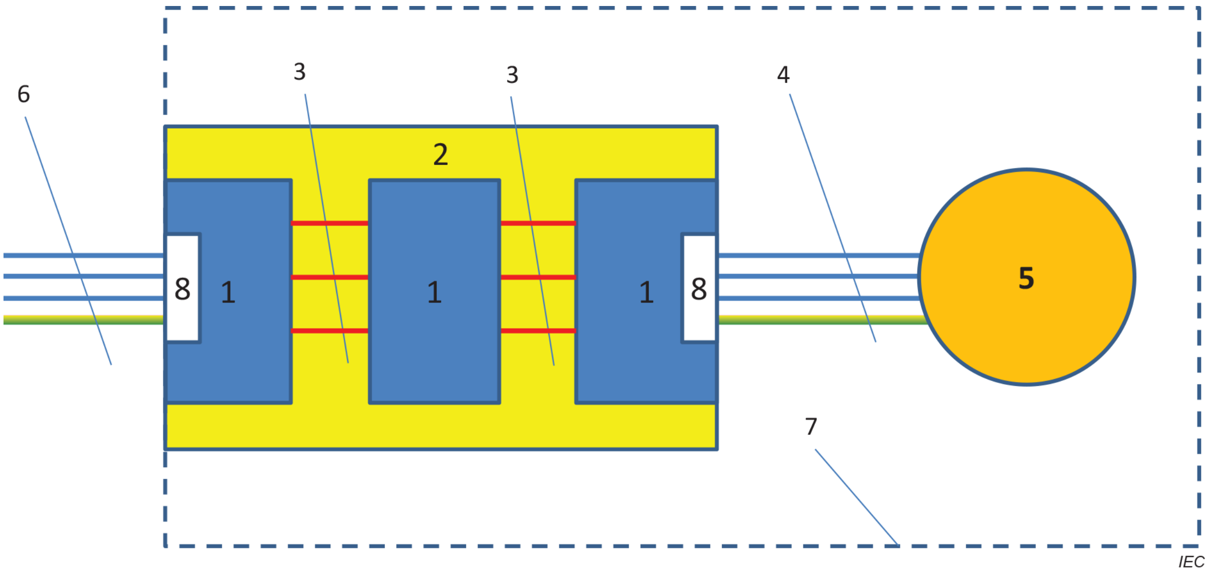
The wiring and interconnections of the *BDM/CDM/PDS* shall be protected from mechanical damage during installation and use. The *insulation*, conductors and routing of all wires of the *BDM/CDM/PDS* shall be suitable for the electrical, mechanical, thermal and environmental conditions of use.

Conductors which are able to contact each other shall be provided with *insulation* rated for the *DVC* requirements of the relevant circuits according to Table 3.

The compliance with 4.11.2 to 4.11.12 shall be checked by *visual inspection* in 5.2.1 of the overall construction and datasheets if applicable.

For marking, see 6.3.7.1, 6.3.7.2, 6.3.7.3 and 6.3.7.4.

An example for interconnections within *BDM/CDM* and between parts of the *PDS* is shown in Figure 7 and Figure 8.



Key:

1 part 1 to *n* of *BDM* or *CDM*

2 *BDM* or *CDM*

3 internal Interconnection of the *BDM* or *CDM*

4 interconnection between parts of the *PDS*

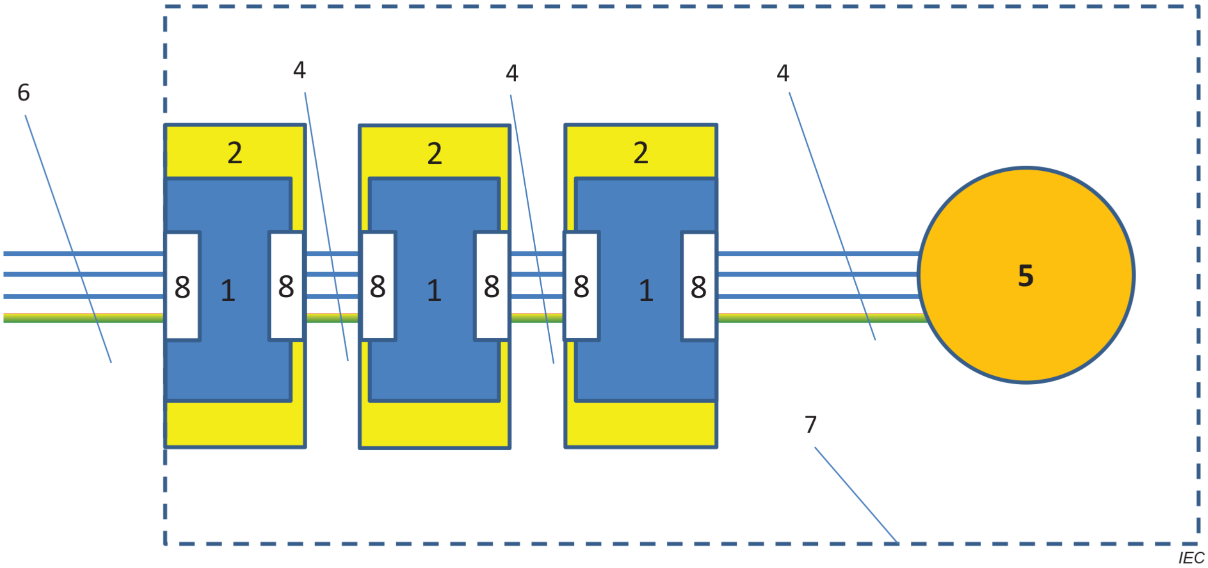
5 load (e.g. motor, braking resistor)

6 supply conductors as part of the *installation*

7 *PDS*

8 *field wiring terminal*

Figure 7 – Example for interconnections within *BDM/CDM* and between parts of the *PDS*



Key:

1 part 1 to *n* of *BDM* or *CDM*

2 *BDM* or *CDM*

3 not used

4 interconnection between parts of the *PDS*

5 load (e.g. motor, braking resistor)

6 supply conductors as part of the *installation*

7 *PDS*

8 *field wiring terminal*

Figure 8 – Example for interconnections between parts of the *PDS* (*BDM/CDM* parts separated by field wiring)

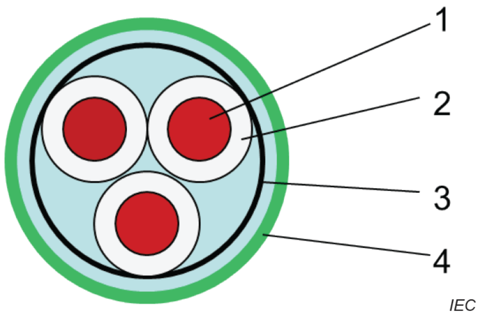
4.11.2 *Insulation* of conductors

4.11.2.1 General

Conductors shall provide *insulation* according to the requirements of this document. This may be achieved either by *clearance* and *creepage distance* or by *solid insulation*.

Non-insulated conductors, for example bus bars, shall be installed to meet the appropriate requirements for *clearance* and *creepage distance*s within the circuit and against other circuits for the *DVC* of the voltage involved according to Table 8 and Table 10.

An example arrangement of insulated conductors in a cable is shown in Figure 9.



Key

1 conductor

2 *insulation* of the conductor (*basic protection*)

3 shield (optional)

4 nonmetallic sheath of the cable (*fault protection*)

Figure 9 – Example arrangement of insulated conductors in a cable

Conductor and cable product standards do not specify *impulse withstand voltage* capability and ability against partial discharge.

However, it is considered for this document that the combination of the *insulation* of the individual conductors and the non-metallic sheath of the cable, whether or not a shield is part of the construction, provides *enhanced protection* according to 4.4.5, if the cable complies with all of the following requirements a), b) and c):

a) the cable complies with an applicable cable product standard;

b) the rated voltage of the insulated conductor or cable shall be not less than the rated voltage within the circuit and against other circuits;

c) the test voltage of the insulated conductors shall comply with the applicable Table 31 or Table 33 for *low-voltage* circuits and Table 32 for high-voltage circuits.

The *insulation* of the conductor is considered *basic protection*, and the non-metallic sheath is considered *fault protection*.

NOTE For more information, see IEC 60364-4-41:2005, Clause B.3.

4.11.2.2 Accessible wiring *system*

Low-voltage wiring *system*s outside of the *enclosure* are considered to meet the requirements of 4.4.3.3, if adequate mechanical protection of the insulated conductors is provided by one or more of the following:

a) a nonmetallic sheath of the cable, provided that the requirements a), b) and c) of 4.11.2.1 are met;

b) an insulated conductor providing *basic insulation* and *fault protection* is provided by

   1) a non-metallic cable duct complying with IEC 61084 (all parts),

   2) a non-metallic conduit complying with IEC 61386 (all parts) or equivalent,

   3) a metallic cable duct or conduit provided that metallic parts are connected with the *protective equipotential bonding system* and comply with 4.4.4.2.2, or

   4) an insulated conductor complying with an applicable insulated conductor product standard and providing *reinforced insulation*.

4.11.2.3 Conductors of different circuits

When there are conductors of different circuits inside a multiconductor cable or occupying the same duct (for example conduit, cable trunking *system*),

- these conductors shall be insulated against all other conductors according to Table 3, or
- all conductors shall have an *insulation* for the highest voltage involved.

If the *insulation* relies on *clearance* and *creepage distance*, means shall be provided to keep the conductors separated.

4.11.3 Stranded wire

The connection points provided shall be of appropriate construction to preclude the possibility of loose strands reducing the *clearance* and *creepage distances* between conductors when careful attention is paid to installation.

When stranded wire or stranded shield is connected to a wire-binding screw, terminal or other provision for connecting, the construction shall be such that loose strands will meet the requirements in 4.4.7.4 and 4.4.7.5 against

- other uninsulated *live parts* (not always of the same potential as the wire), or
- de-energized metal parts.

NOTE These requirements are fulfilled if provisions for connecting are used comprising distances according to the applicable Table S.23 or Table S.24.

4.11.4 Routing and clamping

A hole through which insulated wires pass in a sheet metal wall within the *enclosure* of the *BDM/CDM/PDS* shall be provided with a smooth, well-rounded bushing or grommet or shall have smooth, well-rounded surfaces upon which the wires bear to reduce the risk of abrasion of the *insulation*.

Wires shall be routed away from sharp edges, screw threads, burrs, fins, moving parts, drawers, and similar parts, which abrade the wire *insulation*. The minimum bend radius specified by the wire manufacturer shall not be violated.

Clamps and guides, either metallic or non-metallic, used for routing stationary internal and external wiring shall be provided with smooth, well-rounded edges. The clamping action and bearing surface shall be such that abrasion or damage of the *insulation* does not occur. If a metal clamp is used for conductors having thermoplastic *insulation* less than 0,8 mm thick, non-conducting mechanical protection shall be provided.

4.11.5 Identification of conductors and terminals of *mains supply* and *non-mains supply*

Where the identification of internal conductors, terminals and *field wiring terminals* is considered necessary for safety during installation and/or maintenance, it is in the responsibility of the *BDM/CDM/PDS* manufacturer to choose the appropriate method. Guidance is given in IEC 60445:2021 and IEC 61148:2011.

When identification by colour is used, it shall be at terminations and preferably throughout the length of the conductor either by the colour of the *insulation* or by colour markers, except for bare conductors where the colour identification shall be at termination and connection points.

When identification by colour is used, the colour green-and-yellow shall be used for *protective equipotential bonding* or *PE conductor(s)*. Green-and-yellow colour shall not be used for other purpose. Where a circuit includes a neutral identified by colour, the colour used for this purpose shall be light blue.

The choice of light blue for the neutral conductor and green or green-and-yellow for the *protective equipotential bonding* or *PE conductor* is covered by national regulations. In some countries, the colour code deviates from the above requirement or allows other alternatives.

NOTE In US and Canada, the colour white instead of light blue is used for the neutral conductor. Green instead of green-and-yellow is used for the *PE conductor*.

For insulated conductors which are integral to ribbon cable or multi-cord signal cable, only identified by the colour, the usage of single colours green, yellow and blue is permitted; however, the manufacturer shall provide information and/or marking(s) which clearly indicate the colour code meaning. This shall also prevent mis-identification with earthing or other *system*s that might classically use these colours.

The terminal for connection of the PE-terminal shall be marked according to 6.3.9.2.2.

4.11.6 Splices and connections

All splices and connections shall be mechanically secured and shall provide electrical continuity.

Electrical connections shall be soldered, welded, crimped, or otherwise securely connected. A soldered joint, other than a *component* on a PWB, shall additionally be mechanically secured.

Stranded wire shall not be consolidated with solder where secured in a terminal that relies only on screws or similar means for contact pressure.

When screw terminal connections are used, the resulting connections may require routine maintenance (tightening). Appropriate reference shall be made in the maintenance manual (see 6.5.1).

4.11.7 Accessible connections

In addition to measures given in 4.4.6.5.3, it shall be ensured that neither insertion error nor polarity reversal of connectors can lead to a voltage on an accessible connection higher than the maximum of *DVC As* or any other hazard.

The plugs of the power supply cord of a *BDM/CDM/PDS* shall not fit into the mains socket-outlets of *mains supply system*s at voltages above the rated supply voltage of the *BDM/CDM/PDS*.

NOTE IEC TR 60083 provides information about plugs and socket-outlets for *mains supply system*s.

Mains-type plugs and sockets shall not be used for purposes other than connection of a *mains supply*. This applies for example to plug-in sub-assemblies or other plug-in devices which can be plugged in without the use of a tool or key or which are accessible without the use of a tool or key. This does not apply to *BDM/CDM/PDS* intended to be installed in *restricted-access areas*.

If plug pins of pluggable *BDM/CDM/PDS* receive a charge from an internal capacitor, the pins shall be investigated to 4.4.6.5.3 and 4.4.9.

Test according to 5.2.3.8 shall be conducted, if necessary.

Marking is required on *BDM/CDM/PDS* with mains socket-outlets as follows:

a) if the mains socket-outlet can accept a standard *mains supply* plug, there shall be a marking as specified in 6.3.7.5;

b) if the mains socket-outlet has a terminal contact for a *PE conductor*, the input *mains supply* connection to the *BDM/CDM/PDS* shall include a *PE conductor* connected to a *PE conductor* terminal.

If relevant, non-interchangeability and protection against polarity reversal of connectors, plugs and socket outlets shall be confirmed by *visual inspection* in 5.2.1 and trial insertion.

4.11.8 Interconnections between parts of the *PDS*

Consideration shall be given to the voltage and the current rating of the circuit(s) and the temperature of the *surroundings* for wiring between parts of the entire *PDS*. All sections of the *BDM/CDM/PDS* shall comply with one of the following requirements a), b) or c):

a) applicable subclauses 4.11.2 to 4.11.12;
b) IEC 60364 (all parts);
c) local *installation* rules.

Cable assemblies and flexible cords provided for interconnection between sections of *BDM/CDM/PDS* or between units of a *system* shall be suitable for the service or use involved. For enclosed *BDM/CDM,* cables shall be protected from physical damage as they leave the *enclosure* and shall be provided with mechanical strain relief (see 4.12.6).

Misalignment of male and female connectors, insertion of a multipin male connector in a female connector other than the one intended to receive it, and other manipulations of parts which are accessible to the operator shall not result in mechanical damage or a risk of thermal hazards, electric shock, or injury to persons.

When interconnecting cables terminate in a plug which mates with a receptacle on the external surface of an *enclosure*, no risk of electric shock shall exist at accessible contacts of either the plug or receptacle when disconnected.

Requirements for external interconnecting of *PELV* or *SELV* are given in 4.4.6.5.3.

For internal interconnecting, no requirements are given.

NOTE An *interlock* circuit in the cable to de-energize the accessible contacts whenever an end of the cable is disconnected meets the intent of these requirements.

For information, see IEC 60204-1:2016.

4.11.9 Supply connections for *permanently connected BDM/CDM/PDS*

BDM/CDM/PDS intended to be *permanently connected* to the power supply shall have provision for connection to the applicable wiring *system* in accordance with the requirements where it is being installed.

4.11.10 Supply connections for pluggable *BDM/CDM/PDS*

4.11.10.1 Requirements for cords (for example *mains supply* cords)

NOTE Requirements have been derived from IEC 61010-1:2010, 6.10.1.

The following requirements apply to non-detachable *mains supply* cords and to detachable *mains supply* cords supplied with the *BDM/CDM/PDS* and to similar internal connections. See Figure 10.

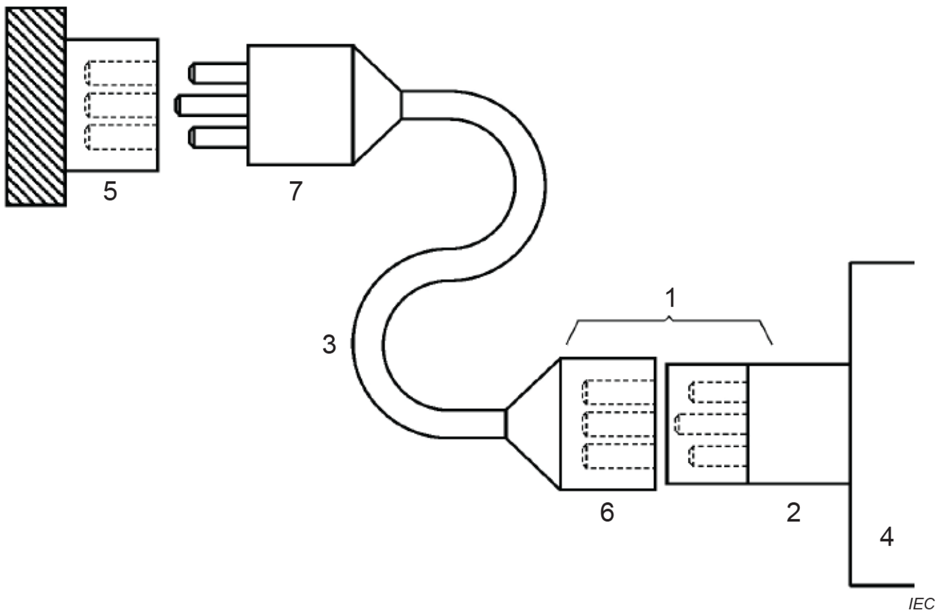
Cords shall comply with 4.11 as applicable and be rated for the maximum current for the *BDM/CDM/PDS*.

If a cord is likely to contact hot external parts of the *BDM/CDM/PDS*, it shall be made of suitably heat-resistant material.

If the cord is detachable, both the cord and the appliance inlet shall have adequate temperature ratings.

The identification of the conductors and terminals shall be according to 4.11.5.

Detachable *mains supply* cords with mains connectors according to the relevant parts of the IEC 60320 series shall either meet the requirements of IEC 60799:2018, or shall be rated at least for the current rating of the mains connector fitted to the cord.



Key

1 appliance coupler

2 appliance inlet

3 cable

4 *BDM/CDM/PDS*

5 fixed mains socket-outlet

6 mains connector

7 mains plug

Figure 10 – Detachable *mains supply* cords and connections

Compliance is checked by *visual inspection* in 5.2.1. Measurement of dimensions should be used if required.

4.11.10.2 Fitting of non-detachable mains supply cords

4.11.10.2.1 Cord entry

Mains supply cords shall comply with 4.11 and be protected against abrasion and sharp bends at the point where the cord enters the *BDM/CDM/PDS*, by one of the following means a) or b):

a) an inlet or bushing with a smoothly rounded opening;

b) reliably fixed flexible cord guard made of insulating material protruding beyond the inlet opening by at least 5 times the overall diameter of a cord with the largest cross-sectional area which can be fitted. For flat cords, the larger cross-sectional dimension is taken as the overall diameter.

Compliance is checked by *visual inspection* in 5.2.1. Measurement of dimensions should be used if required.

4.11.10.2.2 Cord anchorage

The cord anchorage shall comply with the requirements and tests of wiring strain relief in 4.12.6.

4.11.10.2.3 Plugs and connectors

Plugs and connectors for connecting *BDM/CDM/PDS* to the *mains supply*, including appliance couplers used to connect detachable *mains supply* cords, shall conform to the relevant specifications for plugs, *mains socket-outlets* and connectors and shall comply with 4.11.7.

4.11.11 Terminals

4.11.11.1 Construction requirements

All parts of *field wiring terminals* and internal terminals which maintain contact and carry current shall be of metal having adequate mechanical strength.

Terminals shall be such that the conductors can be connected by means of screws, springs or other equivalent means so as to ensure that the necessary contact pressure is maintained.

Terminals shall be constructed so that the conductors can be clamped between suitable surfaces without any significant damage either to conductors or terminals.

Terminals shall not allow the conductors to be displaced or be displaced themselves in a manner detrimental to the operation of *BDM/CDM/PDS* and the *insulation* shall not be reduced below the rated values.

The requirements of 4.11.11.1 are met by using terminals complying with IEC 60947-7 (all parts).

4.11.11.2 Connecting capacity of terminals

Field wiring terminals and internal terminals shall accommodate installation of wiring specified in the documentation (see 6.3.7.4). It shall be possible to perform the installation according to the wiring rules applicable at the *installation.*

The terminals for input power *ports* and output power *port*s shall be sized to cover all of the following applicable requirements:

- the wire size for 125 % of the nominal current at the nominal temperature:
  - the intended material of the conductor for example copper or aluminium;
  - the longest permitted cable length;
- the wire size for the lowest specified motor current intended to be used: the shortest permitted cable length;
- the temperature rating of the intended *insulation* for the conductor;
- the highest *ambient temperature* of the intended *installation* of the motor cable.

NOTE 1 Long cable can cause unallowable voltage drop which can be compensated using a larger wire size.

NOTE 2 Examples for *ambient temperature*: IEC 61439-1 and IEC 60204-1 requires at least 40° C, IEC 60364-5-52 require at least 30 °C for all *installation*s and 20 °C for *installation*s with buried cables.

The terminals shall meet the temperature rise test of 5.2.3.10.

Information regarding the permitted conductor sizes shall be given in the installation manual. See 6.3.7.4.2.

Standard values of cross-section of round copper conductors are shown in Annex G, which also gives the approximate relationship between ISO metric and AWG/MCM sizes.

4.11.11.3 Connection to external conductors by *field wiring terminals*

Field wiring terminals for connection to external conductors shall be readily accessible during installation.

Sets of *field wiring terminals* for connection to the same input *port* or output *port* shall be grouped together.

The *protective earthing* terminal shall be placed in proximity to the input *port* or output *port*, unless marked according to 6.3.9.2.2.

For each connection comprising a neutral conductor, a corresponding *field wiring terminal* shall be provided near to the associated phase conductor terminals.

Means of connection for the *PE conductor* shall comply with 4.4.4.3.2.

4.11.11.4 Wire bending space for wires 10 mm^2 and greater

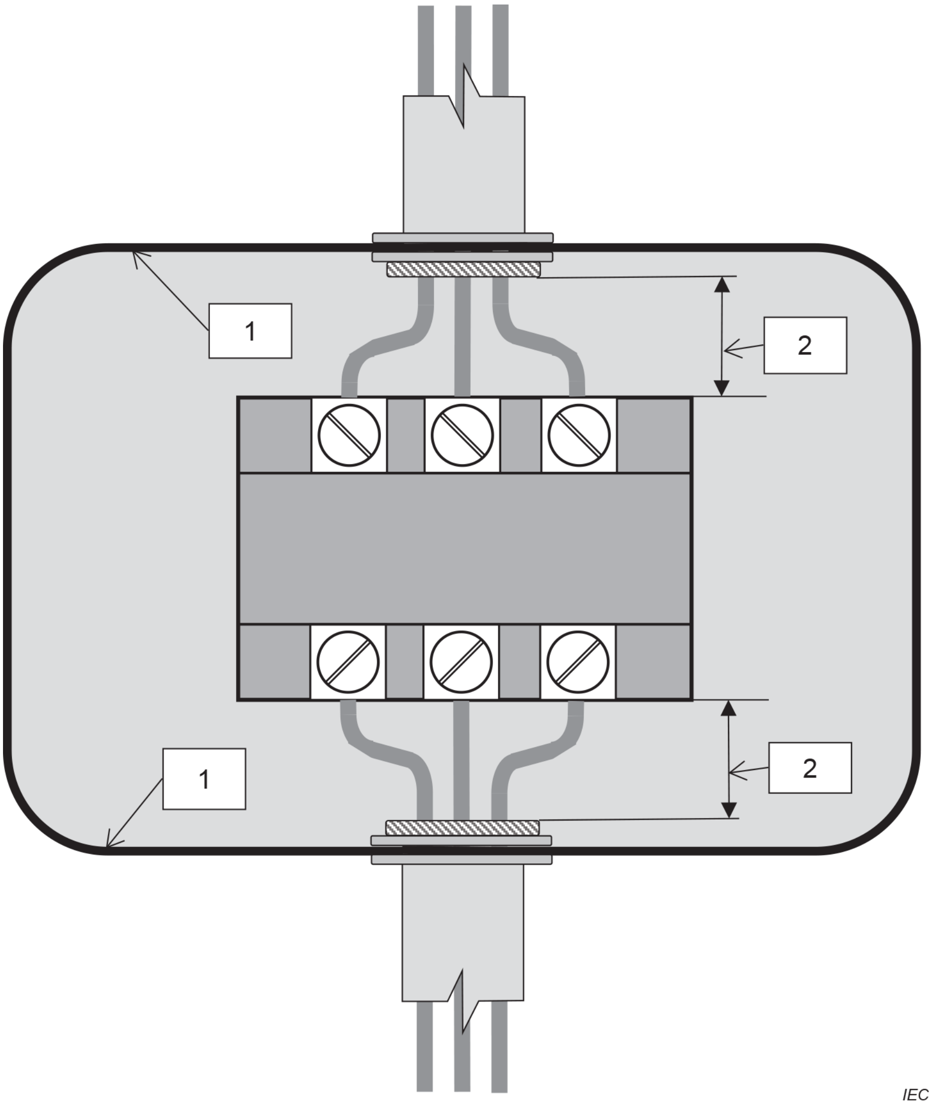
For *low-voltage BDM/CDM/PDS*, the distance between a *field wiring terminal* for connection to the *mains supply* or *non-mains supply*, or between major parts of the *PDS* (for example motor, transformer, *BDM/CDM*), and an obstruction toward which the wire is directed upon leaving the terminal shall be at least that specified in Table 21.

BDM/CDM/PDS designed solely for special application with unique *installation* requirements shall comply with the relevant bending space requirements for that application.

Table 21 – Wire bending space from terminals to *enclosure*

Size of wire mm^2	**Minimum bending space, terminal to *enclosure*** mm		
	Wires per set of terminal		
	1	**2**	**3**
10 to 16	40	-	-
25	50	-	-
35	65	-	-
50	125	125	180
70	150	150	190
95	180	180	205
120	205	205	230
150	255	255	280
185	305	305	330
240	305	305	380
300	355	405	455
350	355	405	510
400	455	485	560
450	455	485	610

Figure 11 shows the evaluation of the wire bending space.



Key

1 *enclosure*

2 wire bending space

Figure 11 – Wire bending space

For *high-voltage BDM/CDM/PDS*, the minimum wire bending space for conductors for interconnection between parts of the *PDS* or to the *mains supply* shall be

- 8 times the overall diameter for non-shielded conductors, or
- 12 times the overall diameter for shielded or lead-covered conductors.

4.11.12 Provisions for connecting the shield of shielded wire or cable

If provisions for connecting the shield of shielded wire or shielded cable are provided, their construction shall comply with 4.4.4.3.2, 4.11.3, 4.11.4, 4.11.11.1 and 4.12.6.

NOTE Shielded wire can be needed to comply with EMC requirements from IEC 61800-3 and functional safety requirements from IEC 61800-5-2.

4.12 Mechanical requirements for *enclosures*

4.12.1 General

The requirements in 4.12 are in addition to *enclosure* requirements given in other subclauses relating to specific hazards, for example electric shock hazard in 4.4, electric energy hazard in 4.5 and fire hazard in 4.6.

Enclosures shall be suitable for use in their intended environment. The manufacturer shall specify the intended environment (see 6.3.3) and the IP rating of the *enclosure* (see 5.2.2.3 for test).

BDM/CDM/PDS shall have adequate mechanical strength and shall be constructed so that no hazard occurs when subjected to such handling as may be expected.

Mechanical strength tests are not required on an internal barrier or similar structure, provided to meet the requirements of 4.6.4.1, if the *enclosure* provides mechanical protection.

An *enclosure* shall be sufficiently complete to contain or deflect parts which, because of failure or for other reasons, might become loose, separated or thrown from a moving part.

For *integrated PDS,* the *BDM/CDM enclosure* shall comply with the above requirements. The motor *enclosure* shall meet the requirements of the relevant parts of the IEC 60034 series.

When ventilation is fan forced by one or more blowers within the *enclosure*, exhaust air shall not blow directly into the area occupied by the operator. This area is defined as 0,75 m wide (horizontal) centered on any operator control, display, or disconnect handle over the entire (vertical) height of the *enclosure* for wall-mounted *BDM/CDM/PDS* or up to 2 m above the floor for floor-standing *BDM/CDM/PDS*.

Compliance shall be checked by the relevant tests of 5.2.2.3 to 5.2.2.6 as specified.

If the *enclosure* complies with the applicable thickness requirement of 4.12.3 or 4.12.4, the test of 5.2.2.4.2 can be omitted.

For *integrated PDS,* the combination of motor and *BDM/CDM* shall be tested according to their intended environment. For external fans and drain holes of the motor part, the requirements of IEC 60034-5:2020 apply.

For *open type BDM/CDM*, the tests of 5.2.2.2 to 5.2.2.6 are not required.

4.12.2 Handles and manual controls

Handles, knobs, grips, levers and the like shall be reliably fixed so that they will not work loose in normal use, if this could result in a hazard. Sealing compounds and the like, other than self-hardening resins, shall not be used as the only means to prevent loosening. If handles, knobs and the like are used to indicate the position of switches or similar *components*, it shall not be possible to fix them in a wrong position if this could result in a hazard.

Compliance shall be checked by *visual inspection* in 5.2.1, and as applicable by the tests of 5.2.2.6.

4.12.3 Cast metal *enclosure*

Die-cast metal, except at threaded holes for conduit, where a minimum of 6,4 mm thickness is required, shall be

- not less than 2,0 mm thick for an area larger than 155 cm^2 or having any dimension larger than 150 mm,
- not less than 1,2 mm thick for an area of 155 cm^2 or less and having no dimension larger than 150 mm.

The area under evaluation may be bounded by reinforcing ribs subdividing a larger area.

Malleable iron or permanent-mould cast aluminium, brass, bronze, or zinc, except at threaded holes for conduit, where a minimum of 6,4 mm thickness is required, shall be

- at least 2,4 mm thick for an area larger than 155 cm^2 or having any dimension larger than 150 mm,
- at least 1,5 mm thick for an area of 155 cm^2 or less and having no dimension larger than 150 mm.

A sand-cast metal *enclosure* shall be a minimum of 3,0 mm thick except at locations for threaded holes for conduit, where a minimum of 6,4 mm is required.

4.12.4 Sheet metal *enclosure*

The thickness of a sheet-metal *enclosure* at points to which a wiring *system* is to be connected (e.g. conduit, receptacles, etc.) shall be not less than

a) 0,8 mm thick for uncoated steel,
b) 0,9 mm thick for zinc-coated steel, and
c) 1,2 mm thick for non-ferrous metal.

Enclosure thickness at points other than where a wiring *system* is to be connected, shall be not less than that specified in Table 22 or Table 23.

With reference to Table 22 or Table 23, a supporting frame is a structure of angle or channel or folded section of sheet metal and has at least one of its dimensions equal to at least one of the outside dimensions of the enclosure surface, and which has torsional rigidity to resist the bending moments that are applied by the *enclosure* surface when it is deflected. A structure which is as rigid as one built with a frame of angles or channels has equivalent reinforcing.

Constructions without supporting frame include

a) a single sheet with single formed flanges/formed edges,
b) a single sheet which is corrugated or ribbed,
c) an *enclosure* surface loosely attached to a frame, for example, with spring clips, and
d) an *enclosure* surface having an unsupported edge.

See Figure 12 for supported and unsupported *enclosure* surfaces.

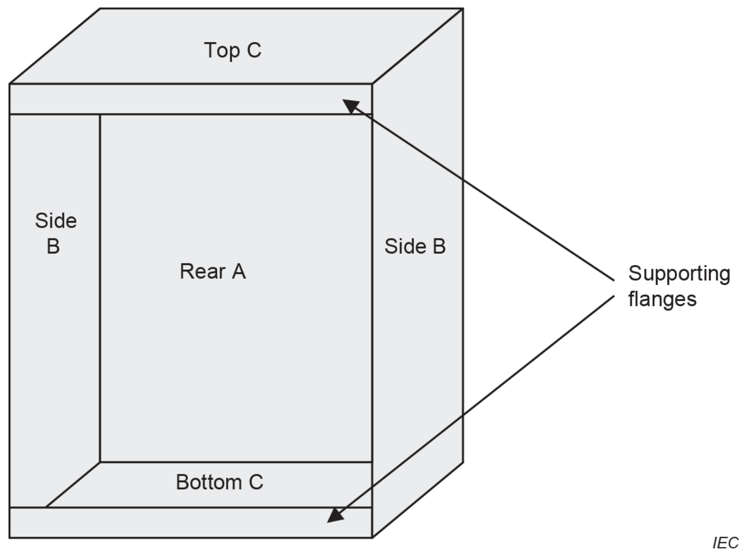


Figure 12 – Supported and unsupported *enclosure* parts

Each *enclosure* surface is evaluated individually based on the length and width dimensions. For each set of surface dimensions, A, B or C, the width is the smaller dimension regardless of its orientation to other surfaces. In Table 22 and Table 23, there are two sets of dimensions that correspond to a single metal thickness requirement and the following describes the applicable procedure for determining the minimum metal thickness for each surface.

For a supported surface, all of the table dimensions, including the "not limited" lengths, are able to be applied. The rear surface "A", top and bottom surfaces "C", are supported either by adjacent surfaces of the *enclosure* or by a 12,7 mm (1/2 inch) wide flange. To determine required metal thickness for supported surfaces, the width shall be measured and compared with the table value in the maximum width column that is equal to or greater than the measured width. When the corresponding length in the maximum length column is "not limited", the minimum thickness in the far right column shall be used. When the corresponding length in the maximum length column is a numerical value, and the measured length of the side does not exceed this value, the minimum thickness from the far right column shall be used. When the measured length of the side exceeds the numerical value, the next row in the Table 22 and Table 23 shall be used.

For an unsupported surface, only the table dimensions that include a specific length requirement are applied. The dimensions with a "not limited" length do not apply. The front edge of the left and right surfaces "B" are not supported by an adjacent surface or by a flange. To determine the required metal thickness for unsupported surfaces, the length shall be measured and compared with the table value in the maximum length column that is not less than the measured length, ignoring the "not limited" entries. When the corresponding width in the maximum width column is not less than the measured width, the minimum thickness from the far right column shall be used. When the measured width of the surface exceeds the value in the maximum width column, the next row in the Table 22 and Table 23 shall be used.

Table 22 – Thickness of sheet metal for *enclosures*: carbon steel or stainless steel

Without supporting frame [a]		With supporting frame [a]		Minimum thickness
Maximum width mm [b]	Maximum length mm [c]	Maximum width mm [b]	Maximum length mm [c]	mm
100 120	Not limited 150	160 170	Not limited 210	0,6 [d]
150 180	Not limited 220	240 250	Not limited 320	0,75 [d]
200 230	Not limited 290	310 330	Not limited 410	0,9
320 350	Not limited 460	500 530	Not limited 640	1,2
460 510	Not limited 640	690 740	Not limited 910	1,4
560 640	Not limited 790	840 890	Not limited 1 090	1,5
640 740	Not limited 910	990 1 040	Not limited 1 300	1,8
840 970	Not limited 1 200	1 300 1 370	Not limited 1 680	2,0
1 070 1 200	Not limited 1 500	1 630 1 730	Not limited 2 130	2,5
1 320 1 520	Not limited 1 880	2 030 2 130	Not limited 2 620	2,8
1 600 1 850	Not limited 2 290	2 460 2 620	Not limited 3 230	3,0

[a] See 4.12.4.

[b] The width is the smaller dimension of a rectangular piece of sheet metal which is part of an *enclosure*. Adjacent surfaces of an *enclosure* can have sup*port*s in common and be made of a single sheet.

[c] "Not limited" applies only when the edge of the surface is flanged at least 12,7 mm or fastened to adjacent surfaces not normally removed in use.

[d] Sheet steel for an *enclosure* intended for outdoor use shall be not less than 0,86 mm thick.

Table 23 – Thickness of sheet metal for *enclosures*: aluminium, copper or brass

Without supporting frame [a]		With supporting frame [a]		Minimum thickness
Maximum width, mm [b]	Maximum length, mm [c]	Maximum width, mm [b]	Maximum length, mm [c]	mm
75 90	Not limited 100	180 220	Not limited 240	0,6 [d]
100 125	Not limited 150	250 270	Not limited 340	0,75
150 165	Not limited 200	360 380	Not limited 460	0,9
200 240	Not limited 300	480 530	Not limited 640	1,2
300 350	Not limited 400	710 760	Not limited 950	1,5
450 510	Not limited 640	1 100 1 150	Not limited 1 400	2,0
640 740	Not limited 1 000	1 500 1 600	Not limited 2 000	2,4
940 1 100	Not limited 1 350	2 200 2 400	Not limited 2 900	3,0
1 300 1 500	Not limited 1 900	3 100 3 300	Not limited 4 100	3,9

[a] See 4.12.4.

[b] The width is the smaller dimension of a rectangular piece of sheet metal which is part of an *enclosure*. Adjacent surfaces of an *enclosure* can have supports in common and be made of a single sheet.

[c] "Not limited" applies only when the edge of the surface is flanged at least 12,7 mm or fastened to adjacent surfaces not normally removed in use.

[d] Sheet aluminium, copper or brass for an *enclosure* intended for outdoor use shall be not less than 0,74 mm thick.

4.12.5 Stability for floor-standing *BDM/CDM/PDS*

Under normal operating conditions, *BDM/CDM/PDS* shall not become physically unstable to the degree that they could become a hazard to an operator or to a service person including tilting.

Measures or information to prevent such hazards shall be provided in the installation instruction.

The requirements of 4.12.5 are not applicable if the installation instructions specify that the *BDM/CDM/PDS* is to be secured to the building structure before operation.

For marking, see 6.4.6.

4.12.6 Wiring strain relief

The wiring of the *PDS*, including the *mains supply* connections and internal cords or cables, shall be protected from strain, including twisting, where they are connected within the *BDM/CDM/PDS*, and the *insulation* of the wiring shall be protected from abrasion (see 4.11.4). The *PE conductor*, if any, shall be the last to take the strain if the wiring slips in its strain relief.

Strain reliefs shall meet the following requirements:

a) the wiring shall not be clamped by a screw which presses directly on the wiring;
b) knots in the wiring shall not be used;
c) it shall not be possible to push the wiring cord into the equipment to an extent which could cause a hazard;
d) failure of the wiring insulation of the cord in the wiring strain relief which has metal parts shall not cause conductive *accessible part*s to become *hazardous live part*s;
e) the wiring strain relief is subjected to a strain relief test using a torque of the value and time shown in Table 27 as close as possible to the external end of the wiring strain relief or bushing;
f) clamps and guides, either metallic or non-metallic, shall be provided with smooth, well-rounded edges to prevent failure of the insulation;
g) it shall not be possible to loosen the wiring strain relief without the use of a tool;
h) the wiring strain relief shall be designed so that wiring replacement does not cause a hazard, and it shall be clear how the relief from strain is provided.

A cable gland shall not be used as a strain relief, unless the cable gland manufacturer's specification states that it is suitable for use as a strain relief.

Compliance is demonstrated by *visual inspection* in 5.2.1 and by the strain relief test in 5.2.2.7.

4.12.7 Polymeric *enclosure* stress relief

Enclosures of moulded or formed thermoplastic materials shall be constructed so that any shrinkage or distortion of the material due to release of internal stresses caused by the moulding or forming operation does not result in the exposure of hazardous parts or in the reduction of *creepage distance*s or *clearance*s according to 4.4.7.4 and 4.4.7.5 below the minimum required.

Compliance shall be checked according to 5.2.2.4.5.

4.12.8 Internal condensation or accumulation of water

In those areas where internal condensation or accumulation of water (see 4.4.7.1.3) is expected,

- *clearance* and *creepage distance*s of Table 8 and Table 10 shall be evaluated at least for pollution degree 3 environment (see Table 5), and
- a provision shall be made to drain water away.

Compliance is checked by *visual inspection* in 5.2.1 according to 5.2.2.3.4.

4.12.9 Polymeric outdoor *enclosure* ultra-violet (UV) resistance

Polymeric parts of an outdoor *enclosure* subjected to UV exposure shall be sufficiently resistant to degradation by UV radiation.

Compliance is checked by

- *visual inspection* according to 5.2.1 of the construction and of available data regarding the UV resistance characteristics of the *enclosure* material and any associated protective coating, or
- test according to 5.2.5.7.

For marking, see 6.3.3.

4.13 *Components*

4.13.1 *Components* general

In addition to the requirement for *components* in the individual clauses of this document, *components* shall comply with 4.13.1 to 4.13.6.

Components identified in 4.2 which are critical to safety shall be used within their specified ratings.

In addition, such *components* shall

- meet the requirements in 4.4 considering electric shock hazard,
- meet the requirements in 4.4.7.1.8 considering the electrical rating for the *insulation* coordination,
- meet the requirements in 4.5 considering energy hazard,
- meet the requirements in 4.6 considering the thermal and fire hazards,
- meet the requirements in 4.7 considering the mechanical hazard,
- meet the requirements in 4.9 considering the environmental conditions, and
- comply with their relevant *component* standard as specified 1) or 2).

Relevant *component* standards are considered to be either

1) the relevant IEC *component* standard, or
2) in absence of a relevant IEC *component* standard, a relevant non-IEC *component* safety standard, issued by a national, international or industry recognized standards development organization.

When a relevant *component* standard does not exist, the *component* shall be subjected to the applicable tests of this document, as part of the *BDM/CDM/PDS*, or individually, whichever creates the more severe condition; however, the *component* shall not be tested and qualified outside of the *component* manufacturer's specified ratings.

NOTE 1 Examples include but are not limited to circuit breakers, fuses, contactors, *components* providing *double insulation* or *reinforced insulation* by design, pressure relief valves, SPDs (MOV, etc.), resistors used as *protective impedance*, etc.

NOTE 2 The applicable test for compliance with a *component* standard is, in general, conducted separately.

NOTE 3 The Bibliography provides an informative list of relevant *component* standards. Further standards might be used.

4.13.2 *Components* representing a fire hazard

Components which could potentially create a fire hazard during *abnormal operating conditions* or *single-fault condition* shall meet the requirement of 4.6.3.

4.13.3 *Components* being part of an *enclosure*

Components providing protection against access to *hazardous live part*s as part of the *enclosure* shall meet the requirements of 4.4.3.3.

Components which are part of a *fire enclosure* according to 4.6.4.2 shall meet the requirement of 4.6.4.3, 4.6.4.4 and 4.6.5.

4.13.4 *Components* representing a mechanical hazard

Components which could potentially create a mechanical hazard during normal operating conditions, *abnormal operating conditions* and *single-fault conditions* shall meet the requirement as specified in 4.7.

4.13.5 Wound *components*

Varnish or enamel *insulation* of wires shall not be used for *basic insulation*, *supplementary insulation*, *double insulation* or *reinforced insulation*.

Wound *components* shall meet the requirements of 4.4.7.8.1, 4.4.7.8.3 (as applicable) and 4.4.7.10.

An insulated winding wire whose *insulation* may be used to provide *basic insulation*, *supplementary insulation*, *double insulation* or *reinforced insulation* in wound *components* shall comply with the requirements of IEC 61558-1:2017, 19.12.3, as applicable.

If the *component* has *reinforced insulation* or *double insulation*, the AC or DC voltage test of 5.2.3.4 shall be performed as a *routine test* with the values for *basic protection*.

4.13.6 Protective devices

Components acting as a protective device for compliance to the tests in 5.2.4 shall comply with 4.13.1.

4.14 Protection against electromagnetic fields

To protect persons against electromagnetic fields, the exposure shall be limited either by the *BDM/CDM/PDS* itself or with external measures.

For more information, refer to Annex P.

For compliance, see 5.2.8.

5 Test requirements

5.1 General

5.1.1 Test objectives and classification

Testing, as defined in this Clause 5, is required to demonstrate that *BDM/CDM/PDS* is fully in accordance with the requirements of this document for the intended use, normal operating conditions, *abnormal operating condition*s and *single-fault condition*s. Testing may be omitted if permitted by the relevant requirements in Clause 4.

Clause 5 describes the procedures to be adopted for the testing of *BDM/CDM/PDS*. The tests are classified as

- *type tests*,
- *routine tests*, and
- *sample tests*.

WARNING – These tests can result in hazardous situations. Suitable precautions are necessary to avoid injury.

5.1.2 Selection of test samples

When testing a range or series of similar products, it may not be necessary to test all models including *accessories* in the range. Each test shall be performed on a model or models having mechanical and electrical characteristics that adequately represent the entire range for that particular test.

For further detailed instructions on sample selection, see 5.1.5.2.

5.1.3 Sequence of tests

In general, there is no requirement for tests to be performed in a set sequence, nor is it required that they are all performed on the same sample of *BDM/CDM/PDS*. However, the acceptance criteria for some of the tests require that they are followed by one or more further tests.

5.1.4 Earthing conditions

Test requirements shall be determined using the worst-case (most stressful) earthing *system* in 4.4.7.1.5 and specified by the manufacturer.

See also 4.4.7.1.7 and 6.2.1.

5.1.5 General conditions for tests

5.1.5.1 Application of tests

The *BDM/CDM/PDS* shall be capable to operate upon conclusion of the test unless the specific testing subclause provides additional information.

5.1.5.2 Selecting of test samples

Unless otherwise specified, the sample or samples under test shall be representative of the *BDM/CDM/PDS* the user would receive.

As an alternative to carry out tests on the complete *BDM/CDM/PDS*, tests may be conducted separately on circuits, *components* or sub-assemblies outside the *BDM/CDM/PDS*, provided that *visual inspection* in 5.2.1 of the *BDM/CDM/PDS* and circuit arrangements indicate that the results of such testing will be representative of the results of testing the assembled *BDM/CDM/PDS*. If any such test indicates a likelihood of non-conformance in the complete *BDM/CDM/PDS*, the test shall be repeated in the *BDM/CDM/PDS*.

Where in this document compliance of materials, *components* or sub-assemblies is checked by *visual inspection* in 5.2.1 or by testing of properties, it is permitted to confirm compliance by reviewing any relevant data or previous test results that are available instead of carrying out the specified *type tests*. See also 4.1.

EXAMPLE Tests on *enclosures* of the same material but different sizes can be represented by a single *enclosure* but tests on power *components* that have different ratings often cannot be represented by testing on one particular model.

5.1.5.3 Operating parameters for tests

Unless otherwise specified in a specific test clause, the test conditions of Table 24 apply.

Table 24 – Environmental conditions for tests

Temperature °C	Relative humidity %	Air pressure kPa
15 to 35	25 to 75	86 to 106
Source: IEC 60068-1:2013, Table 2. NOTE If the above conditions are not achievable, tests can be performed within the rated range of the climatic conditions of the *BDM/CDM/PDS*.		

Except where specific test conditions are stated elsewhere in this document and where it is clear that there is a significant impact on the results of the test, the tests shall be conducted under the most unfavourable combination within the manufacturer's operating specifications of the following parameters:

- rated input voltage;
- rated input frequency; or DC
- operating temperature range taking into account derating and cooling control characteristic;
- physical location of *BDM/CDM/PDS* and position of *movable* parts;
- operating mode;
- load conditions;
- adjustment of thermostats, regulating devices or similar controls in *service-access area*, which are
  - adjustable without the use of a tool or key, or
  - adjustable using a means, such as a key or a tool, deliberately provided for the operator.

BDM/CDM/PDS rated for AC supplies within the range of 50 Hz to 60 Hz shall be tested at a frequency in the range of 48 Hz to 62 Hz.

5.1.5.4 Mounting

Each *BDM/CDM/PDS* shall be mounted as described in the manufacturer's installation instructions. When the installation instructions specify more than one mounting position, an analysis shall be made to determine the mounting position(s) that will result in the worst case test condition.

5.1.6 Compliance

Compliance with this document shall be verified by carrying out the relevant tests specified in Clause 5.

Compliance may only be claimed if all relevant tests have been passed.

Compliance with construction requirements and information to be provided by the manufacturer shall be verified by suitable examination, *visual inspection* in 5.2.1, and/or measurement.

Whenever design or *component* changes have potential impact upon compliance, a new *type test* or technical evaluation (for example through calculation) shall be performed to confirm compliance.

5.1.7 Test overview

Table 25 provides an overview of the *type test*, *routine test* and *sample test* of electronic *components*, devices and *BDM/CDM/PDS*.

Table 25 – Test overview

Test	*Type*	*Routine*	*Sample*	Requirement(s)	Specification
General verification					
Visual inspection	X	X	X		5.2.1
Mechanical tests					5.2.2
Clearance and *creepage distance*s test	X			4.4.7.4, 4.4.7.5	5.2.2.1
Non-accessibility test	X			4.4.3.3, 4.7.5	5.2.2.2
Ingress protection test (IP rating)	X			4.12.1	5.2.2.3
Atomized water test	X			4.12.1	5.2.2.3.2
IEC 60529 *enclosure* category 1 or 2 test for IP5X	X			-	5.2.2.3.3
Accumulation of water test	X			4.12.8	5.2.2.3.4
Enclosure integrity test	X			4.12.1	5.2.2.4
Deflection test	X			4.4.7.4.5, 4.12.1	5.2.2.4.2
Steady force test, 30 N	X			4.4.7.4.5, 4.12.1	5.2.2.4.2.2
Steady force test, 250 N	X			4.4.7.4.5, 4.12.1	5.2.2.4.2.3
Impact test	X			4.12.1	5.2.2.4.3
Drop test	X			4.12.1	5.2.2.4.4
Mould stress relief distortion test	X			4.12.7	5.2.2.4.5
Wall or ceiling mounted test	X			4.12.1	5.2.2.5
Handles and manual control securement test	X			4.12.2	5.2.2.6
Strain relief test	X			4.11.10.2.2, 4.12.6	5.2.2.7
Isolating means and interlock integrity test	X			4.4.10.1, 4.4.10.2.1.1	5.2.2.8
Acoustic noise test	X			4.10.2	5.2.2.9
Electrical tests					
Impulse withstand voltage test	X		X	4.4.3.2, 4.4.5.4, 4.4.7, 4.4.7.10.1, 4.4.7.10.2, 4.4.7.10.3, 4.4.7.8.3, 5.2.2.1	5.2.3.2
Alternative to impulse withstand voltage test	X		X	-	5.2.3.3
AC or DC voltage test	X	X		4.4.3.2, 4.4.5.4, 4.4.7.10.1, 4.4.7.10.2, 4.4.7.10.3, 4.4.7.8.4.3	5.2.3.4
Partial discharge test	X		X	4.4.7.8	5.2.3.5
Protective impedance test	X	X		4.4.5.4	5.2.3.6
Touch current measurement test	X			4.4.4.3.3	5.2.3.7
Capacitor discharge test	X			4.4.9	5.2.3.8
Limited power source test	X			4.5.2, 4.5.3	5.2.3.9
Temperature rise test	X			4.6.5	5.2.3.10
Protective equipotential bonding test	X	X		4.4.4.2	5.2.3.11
Protective equipotential bonding continuity test	X	X		4.4.4.2.2	5.2.3.11.2
Input test	X			6.2.1	5.2.3.12
Thin sheet material test	X			4.4.7.8.3	5.2.3.13

Test	*Type*	*Routine*	*Sample*	Requirement(s)	Specification
Test procedure for separable thin sheet material	X			4.4.7.8.3	5.2.3.13.2
Mandrel test	X		X	4.4.7.8.3	5.2.3.13.3
Test procedure for determination of working voltage	X			4.4.7.1.2	5.2.3.14
Internal SPD monitoring test	X			4.4.7.2.2	5.2.3.15
Preconditioning of material	X			4.4.7.8.4.2, 4.4.7.8.4.3, 4.4.7.9	5.2.3.16
***Abnormal operation* and simulated faults tests**					
Protective equipotential bonding short-circuit withstand test	X			4.3.1, 4.3.2.2, 4.4.4.2	5.2.4.4
Output short-circuit test	X			4.3.2.2, 4.3.2.3, 4.3.3	5.2.4.5
Short-circuit test between phase terminals of output power *port*	X			4.3.1	5.2.4.5.2
Short-circuit test between phase terminals of output power *port*s and earth	X			4.3.1	5.2.4.5.3
Electronic motor overload protection test	X			4.3.5	5.2.4.6.4
Electronic motor thermal memory retention trip test	X			4.3.5	5.2.4.6.5
Electronic motor thermal memory retention loss of power test	X			4.3.5	5.2.4.6.6
Electronic motor thermal speed sensitivity test	X			4.3.5	5.2.4.6.7
Circuit functionality evaluation test	X	X	X	5.2.4.5, 5.2.4.6,	5.2.4.7
Current limiting test	X			4.3.6	5.2.4.8
Output overload test	X			4.6.1	5.2.4.9
Breakdown of components test	X			4.2, 4.3.2.2	5.2.4.10
PWB short-circuit test	X			4.4.7.7	5.2.4.11
Loss of phase test	X			4.2	5.2.4.12
Cooling failure tests	X			4.2, 4.7.4.3.7	5.2.4.13
Inoperative blower motor test	X			4.2	5.2.4.13.2
Clogged filter test	X			4.2	5.2.4.13.3
Loss of coolant test	X			4.7.4.3.7	5.2.4.13.4
Covering of openings for cooling air test	X			4.2	5.2.4.13.5
Material tests				4.4.7.8.2, 4.6.4.2	5.2.5
High current arcing ignition test	X			4.4.7.8.2	5.2.5.2
Glow-wire test	X			4.4.7.8.2	5.2.5.3
Hot wire ignition test	X			4.4.7.8.2	5.2.5.4
Flammability test	X			4.6.4.2	5.2.5.5
Cemented joints test	X			4.4.7.9	5.2.5.6
UV resistance test	X			4.12.9	5.2.5.7
Environmental tests	X			4.9	5.2.6
Preconditioning or recovery procedure for climatic tests	X			4.9	5.2.6.3.1
Dry heat test (steady state)	X			4.9	5.2.6.3.2

Test	*Type*	*Routine*	*Sample*	Requirement(s)	Specification
Cold test (steady state)	X			4.9	5.2.6.3.3
Damp heat test (steady state)	X			4.9	5.2.6.3.4
Damp heat test (cyclic)	X			4.9	5.2.6.3.5
Vibration test	X			4.9	5.2.6.4
Salt mist test	X			4.9	5.2.6.5
Dust test	X			4.9	5.2.6.6
Sand test	X			4.9	5.2.6.7
Hydrostatic pressure test	X	X		4.7.4.3.3	5.2.7
Electromagnetic fields (EMF)	X			4.14	5.2.8

5.2 Test specifications

5.2.1 *Visual inspection*s (*type test*, *routine test* and *sample test*)

*Visual inspection*s shall be made

- as *routine tests*, to check features such as adequacy of labelling, warnings and other safety aspects, and
- to verify
  - the relevant design measures and data sheets as specified in 4.3 to 4.14,
  - the acceptance criteria of individual tests in 5.2.2 to 5.2.7, and
  - relevant information and marking requirement as specified in 6.2 to 6.5.

Routine *visual inspection*s may be part of the production or assembly process.

Before performing a *type test*, a check shall be made that the *BDM/CDM/PDS* delivered for the test is as expected with respect to supply voltage, input and output ranges, etc.

5.2.2 Mechanical tests

5.2.2.1 *Clearance*s and *creepage distance*s test (*type test*)

It shall be verified by measurement and *visual inspection* in 5.2.1 that the *clearance* and *creepage distance*s comply with 4.4.7.4 and 4.4.7.5. See Annex D for measurement examples.

The *impulse withstand voltage* test (see 5.2.3.2) shall be performed as close as possible to the distance under consideration

- where this measurement or *visual inspection* in 5.2.1 is impossible to perform, but constructional documentation shows compliance with 4.4.7.4 and 4.4.7.5, or
- in case the *clearance* is designed for homogeneous field conditions in 4.4.7.4.4.

5.2.2.2 Non-accessibility test (*type test*)

This test is intended to show that *hazardous live parts* and hazardous moving parts, for example fan blades, are protected by means of *enclosures* or barriers complying with 4.4.3.3 and 4.7.5.

This test shall be performed as a *type test* of the *enclosure* of a *BDM/CDM/PDS* as specified in IEC 60529 for the *enclosure* classification for protection against access to hazardous parts, except as noted below.

The test probes from IEC 61032:1997 shall apply and are reproduced in Annex M.

Test 1 (Protection against access with a finger, IP2X, IPXXB):

When the jointed test finger according to Figure M.2 is inserted into any opening of an *enclosure* or barrier with a force of 10 N ± 10 % and bended into any direction,

- the test finger shall not touch hazardous moving parts, (see 4.7.5.2),
- adequate clearance to the *hazardous live parts* shall be maintained (see 4.4.3.3.1 and 4.4.3.3.2), and
- the test finger shall not bridge parts between which a hazardous electrical energy exists (see 4.5.1).

Test 2 (Protection against solid foreign objects, IP2X):

When the full diameter of the sphere of 12,5 mm according to Figure M.4 is inserted into any opening of an *enclosure* or barrier with a force of 30 N ± 10 %, the test probe shall not pass completely through the openings (see 4.4.3.3.1).

Test 3 (Protection against access with the back of the hand, IPXXA):

When the 50 mm test probe according to Figure M.1 is used to demonstrate protection against unintended contact where the *enclosure* is intended to be opened by *skilled person*s and the *BDM/CDM/PDS* energized during installation or maintenance,

- the test probe shall not pass completely through the openings (see 4.4.3.3.2),
- the test probe shall not touch hazardous moving parts, and
- adequate clearance to the *hazardous live parts* shall be maintained (see 4.4.3.3.2).

Test 4 (Protection against access to hazardous parts with a tool, IPXXC, top surface):

When the 2,5 mm test rod according to Figure M.3, is inserted into the top surface of an *enclosure* or barrier from the vertical direction limited to ±5 ° with a force of 3 N ± 10 %, adequate clearance to the *hazardous live part*s shall be maintained (see 4.4.3.3.5.1).

NOTE IPXXC allows the test probe to enter the *enclosure* (similar to example shown for IP1XD in IEC 60529:1989, Annex A, reference 8).

For compliance, see 5.2.2.1 and Table A.1 considering the appropriate test probe.

The test probes from IEC 61032:1997 are reproduced in Annex M.

5.2.2.3 Ingress protection test (IP rating) (*type test*)

5.2.2.3.1 General

As required in 4.12.1, the claimed IP rating of the *enclosure* shall be verified. This test shall be performed as a *type test* of the *enclosure* of a *BDM/CDM/PDS* as specified in IEC 60529 for the *enclosure* classification.

In conjunction with IEC 60529:1989, 11.2, the following applies.

a) One representative sample shall be tested.
b) The enclosure shall be mounted for test as described in 5.1.5.4.
c) Testing can be done with an empty enclosure or an enclosure that does not contain all the parts that would be included in the complete product if it can be proven that the removal of these parts does not impact the test results. The manufacturer is required to provide evidence that the ingress of water or dust will not violate the acceptance criteria for the relevant characteristic numeral IP test.

d) For large enclosures having a volume greater than 2 m^3, if an enclosure is comprised of many identical seams (a joint between two or more pieces) with similar fastening patterns, it is permissible to test one representative joint. This would include doors, panels, shipping splits, access panels, or any mechanical structure of the enclosure that is a potential ingress point where the construction is duplicated multiple times in the same enclosure.

e) The BDM/CDM/PDS shall be tested considering the most severe requirement of the following conditions:
   - energized;
   - not energized;
   - moving parts in motion;
   - moving parts not in motion.

Analysis can be used to show that the most severe test condition may be omitted if that test condition has no effect on the results of the test. Technical justification for test configuration shall be documented with test results.

Paint or paste that changes colour when exposed to water which allows the water path to be tracked or video equipment installed inside the *enclosure* may be used. There may be other acceptable methods not mentioned. It is the manufacturer's responsibility to ensure compliance is met with the removal of equipment.

The test methods described in IEC 60529:1989, Figure 4 and Figure 5, are allowed when performing IPX3 and IPX4 testing as referenced in IEC 60529:1989, 14.2.3 and 14.2.4.

The atomized water test of 5.2.2.3.2 is allowed to be used in place of a dust test for IP5X and IP6X ratings if the *enclosure* is of category 2 in 5.2.2.3.3. When this test is used, it is allowed to rate the product to IP5X or IP6X at the manufacturer's discretion. An IP5X rating may be required after the atomized water test, if the filter medium only has an IP5X rating.

See 5.2.2.3.2 for test.

It is not acceptable to test ventilation openings using the atomized water test method for IP5X or IP6X. However, the gasket between the ventilation opening and housing may be tested using this method.

The atomized water test cannot be used to determine how dust would accumulate inside the *enclosure*, which might lead to a hazardous condition. Therefore, the more stringent requirements of IP6X are imposed. It is possible that, with the inclusion of filters, an IP5X rating may be required for the *BDM/CDM/PDS* based on the qualification of the filter. See 4.12.1 for requirements of the IP rating.

5.2.2.3.2 Atomized water test (*type test*)

The gasketed *enclosure* seam shall be subjected to a spray of atomized water using a two-fluid nozzle which produces a round pattern 75 mm to 100 mm in diameter when measured 300 mm or less from the nozzle. The air pressure shall be adjusted to at least 200 kPa and the flow rate to at least 11,4 l/h.

NOTE 1 The atomized water test is taken from NEMA 250.

NOTE 2 The atomized water test can be used to test the complete *enclosure* or any geometry involving any gasket built as a sub-assembly because the gasket cannot be validated on the final *BDM/CDM/PDS*.

The nozzle shall be held at a distance between 300 mm to 350 mm from the *enclosure* gasket and the spray of water shall be directed one time at all points of potential dust entry. Movement along dust entry locations shall occur at a rate of linear 0,5 cm/s or less.

The test shall be considered to have met the requirements of IP5X and IP6X if, at the conclusion of the test, no water has entered the *enclosure*.

As determined by 5.2.2.3.3, a vacuum is applied during this test according to the requirements for category 1 *enclosure*s per IEC 60529 for IP5X *enclosure*s where the normal working cycle of the *BDM/CDM/PDS* causes reductions in air pressure within the *enclosure* below that of the surrounding air (e.g thermal cycling effects).

For IP5X *enclosure*s where no pressure difference relative to the surrounding air is present as determined by 5.2.2.3.3, no vacuum is applied for the test.

A vacuum shall be applied during the test for all IP6X *enclosure*s according to the requirements for category 1 *enclosure*s per IEC 60529.

5.2.2.3.3 IEC 60529 *enclosure* category 1 or 2 test for IP5X (*type test*)

To determine whether the IP5X *enclosure* is category 1 or 2, the following test shall be performed. The test is performed while measuring the internal atmospheric pressure of the *enclosure* and the atmospheric pressure just outside the *enclosure* along with all thermal data points required inside the *enclosure*, in the prescribed order:

1) starting from an "OFF state" with all parts at room ambient;
2) operating the *BDM/CDM/PDS* at full load until temperature stability is reached;
3) returning the *BDM/CDM/PDS* to is "OFF state" with all parts at room *ambient temperature*.

During the test, holes or openings shall either

- use IP5X minimum filters, or
- be sealed.

During the test, the internal pressure of the *enclosure* shall not decrease below the external pressure at any time by 2 kPa. If this result is achieved, the *BDM/CDM/PDS* is deemed category 2 and no vacuum is applied for the test.

5.2.2.3.4 Accumulation of water test (*type test*)

When required in 4.12.8, it shall be proved by *visual inspection* in 5.2.1 that

- *clearance* and *creepage distance* in accordance with 4.4.7.4 and 4.4.7.5 is maintained between *hazardous live part*s and the accumulated water, where water is considered a conductive part (see Table A.1), and
- the *enclosure* includes a drain or other means to eliminate the accumulation of water and drains the water away.

If compliance cannot conclusively be determined by *visual inspection* in 5.2.1, the AC or DC voltage test (*type test*) of 5.2.3.4 shall be performed.

Water accumulation in areas of the *enclosure* that do not violate the acceptance criteria in 5.2.2.3.5 is acceptable.

5.2.2.3.5 Acceptance criteria

5.2.2.3.5 is intended to be used in conjunction with the acceptance criteria listed in IEC 60529.

For second characteristic numerals 1 through 6 defined in IEC 60529, if any water has entered the *enclosure*, it shall not

a) be sufficient to interfere with the correct operation of the *BDM/CDM/PDS* or impair safety,
b) deposit on insulation parts where it could lead to tracking along the *creepage distances*,
c) reach *live part*s,

d) accumulate near the cable end or enter the cable, if any,

e) accumulate near a cable entrance or exit, and

f) decrease the *clearance* and *creepage distances* required in 4.4.7.4 and 4.4.7.5 between *hazardous live part*s and the accumulated water.

5.2.2.4 *Enclosure* integrity test (*type test*)

5.2.2.4.1 General

The *enclosure* integrity tests apply to *BDM/CDM/PDS*, and also where *BDM/CDM/PDS* are intended for operation without a further *enclosure* in *restricted-access areas*.

The *enclosure* integrity tests shall be performed at the worst case point on representative accessible surface(s) of the *enclosure*.

After completion of the *enclosure* integrity test, the *BDM/CDM/PDS* shall pass the electrical tests of 5.2.3.2 and 5.2.3.4 and shall be inspected to confirm that

a) no degradation of any safety-relevant *component* of the *BDM/CDM/PDS* has occurred,

b) *hazardous live part*s have not become accessible (see 4.4.3.3),

c) *enclosures* show no cracks or openings which could cause a hazard,

d) *clearances* are not less than their minimum required values and other insulation is undamaged,

e) barriers have not been damaged or loosened, and

f) no moving parts which could cause a hazard are exposed.

The *BDM/CDM/PDS* is not required to be operational after testing, and the *enclosure* may be deformed to such an extent that its original IP rating is not maintained.

5.2.2.4.2 Deflection test (*type test*)

5.2.2.4.2.1 General

If requested by 4.4.7.4.5 or 4.12.1, the test in 5.2.2.4.2.2 and 5.2.2.4.2.3 applies for metallic *enclosure*, as applicable.

The *enclosure* shall be held firmly against a rigid support.

The tests are not applied to handles, levers, knobs or to transparent or translucent covers of indicating or measuring devices, unless *hazardous live part*s are accessible by means of jointed test finger according to Figure M.2, if the handle, lever, knob or *cover* is removed.

After the tests of 5.2.2.4.2.2 and 5.2.2.4.2.3, earthed or unearthed conductive *enclosures* shall

- not reduce *clearance* (4.4.7.4) and *creepage distance*s (4.4.7.5) to *live part*s required for *basic insulation*, or
- withstand the *impulse withstand voltage* test in 5.2.3.2 for *basic insulation*.

Damage to the finish, small dents and small chips which do not adversely affect the protection against electric shock or moisture may be ignored.

5.2.2.4.2.2 Steady force test, 30 N

Parts of an *enclosure* located in *service-access areas* or *restricted-access areas*, which are protected by a *cover* or *door* meeting the requirements of 5.2.2.4.2.3, are subjected to a steady force of 30 N ± 3 N for a period of 5 s, applied by means of a straight unjointed version of jointed test finger according to Figure M.2, to the part on or within the *BDM/CDM/PDS*.

5.2.2.4.2.3 Steady force test, 250 N

Enclosure or external surfaces of the *enclosures* are subjected to a steady force of 250^{+10}_{-0} N, for a period of not less than 5 s, applied in turn to the top, bottom and sides of the *enclosure* fitted to the *BDM/CDM/PDS*, through the end of a rod having a 12,7 mm by 12,7 mm square, flat steel face.

For surfaces neither horizontal nor vertical, test shall be performed by tilting the *BDM/CDM/PDS* in a suitable way so that the surface is either horizontal or vertical.

5.2.2.4.3 Impact test (*type test*)

External polymeric surfaces of *enclosures*, the failure of which would give access to hazardous parts, are tested as follows.

A sample consisting of the complete *enclosure*, or a portion thereof representing the largest unreinforced area, is supported in its normal position. A solid smooth steel ball, approximately 50 mm in diameter and with a mass of 500 g ± 25 g, is permitted to fall freely from rest through a vertical distance (H) of 1,3 m (see Figure 13) onto the sample. Vertical surfaces are exempt from this test.

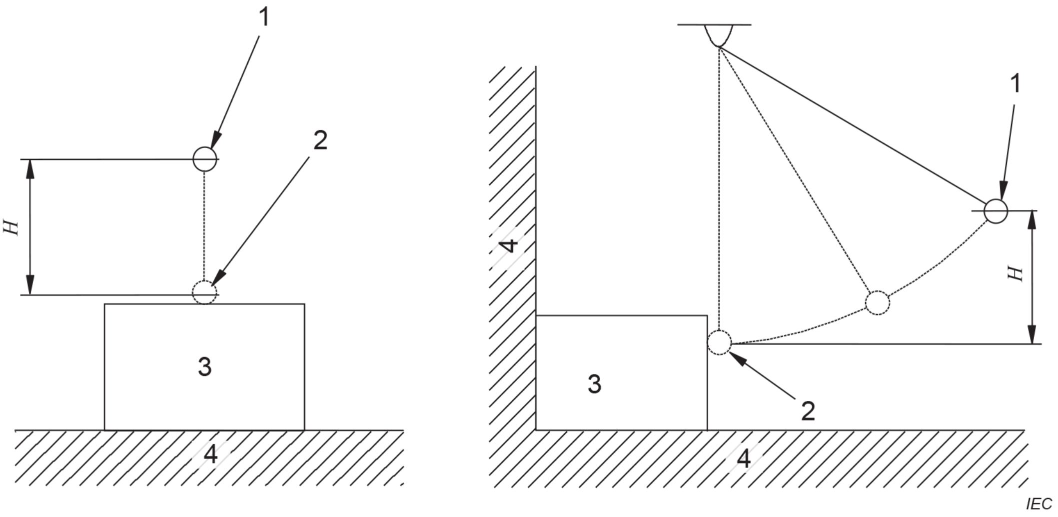
In addition, the steel ball is suspended by a cord and swung as a pendulum in order to apply a horizontal impact, dropping through a vertical distance (H) of 1,3 m (see Figure 13) onto the sample. Horizontal surfaces are exempt from this test.

The sample is preconditioned for a period of 3 h at the lowest temperature the manufacturer specifies for operation, storage or transportation. The sample is then allowed to rise to the lowest operation temperature and kept there for a period of 3 h, then tested immediately after preconditioning at normal laboratory conditions as specified in Table 24.

If analysis shows that the result will be the same as non-rotated *BDM/CDM/PDS*, as an alternative, the sample can be rotated 90° about each of its horizontal axes and the ball dropped as in the vertical impact test.

NOTE In Canada, the following requirements apply.

- All surfaces must be tested with the vertical impact test.
- For an *enclosure* in which any surface area is more than 260 cm^2, the impact must be produced by dropping the same sphere from a height of 2 600 mm.
- Three samples must be tested in ambient of Table 24.
- Three samples must be cooled to 0 °C and maintained at that temperature for 3 h. Immediately following removal from the cold chamber, the samples must be subjected to the impact test in ambient of Table 24.



Key

1 steel ball start position

2 steel ball impact position

3 test sample

4 rigid supporting surface

Figure 13 – Impact test using a steel ball

5.2.2.4.4 Drop test (*type test*)

Hand-held BDM/CDM/PDS, direct plug-in *BDM/CDM/PDS* and *movable BDM/CDM/PDS* with mass of 18 kg or less is subjected to the following test.

A sample of the complete *BDM/CDM/PDS* is subjected to one impact on each position of 3 corners, 3 edges and each face that result from being dropped onto a sufficiently rigid horizontal surface.

The following is considered to be a sufficiently rigid horizontal surface for the drop test:

- a hardwood board at least 13 mm thick, mounted on two layers of plywood each 19 mm to 20 mm thick, all supported on a concrete or equivalent non-resilient floor, or
- a hardwood board of 50 mm thick and having a density of more than 700 kg/m^3 lying flat on a rigid base such as concrete or equivalent non-resilient floor.

The height of the drop shall be

- 1 000 mm for *hand-held BDM/CDM/PDS* and direct plug-in *BDM/CDM/PDS*, and
- 750 mm for movable *BDM/CDM/PDS*.

NOTE Test requirements and severity are aligned with IEC 60068-2-31:2008, 5.2 (free fall procedure 1), by consideration of unpacked product.

5.2.2.4.5 Mould stress relief distortion test (*type test*)

When required in 4.12.7, compliance of *enclosures* of moulded or formed thermoplastic materials shall be checked by the test procedure described below or by the *visual inspection* in 5.2.1 of the construction and the available data where appropriate.

One sample consisting of the complete *BDM/CDM/PDS*, or of the complete *enclosure* together with any supporting framework, is tested at a temperature 10 K higher than the maximum temperature of the *enclosure* during the temperature rise test of 5.2.3.10, but not less than 70 °C, for a period of 7 h, then permitted to cool at room temperature.

NOTE More information can be found in IEC 60695-10-3.

For large *BDM/CDM/PDS* where it is impractical to condition a complete *enclosure*, it is permitted to use a portion of the *enclosure* representative of the complete assembly with regard to thickness and shape, including any mechanical support members.

5.2.2.5 Wall or ceiling mounted test (*type test*)

When required in 4.12.1, the *BDM/CDM/PDS* shall demonstrate adequate mechanical strength for the intended use, either by test in 5.2.2.5 or calculation or simulation.

The *BDM/CDM/PDS* shall be mounted in accordance with 5.1.5.4.

An external force in addition to the mass of the *BDM/CDM/PDS* is applied downwards through the geometric centre of the *BDM/CDM/PDS* (on top or bottom), for 1 min.

The additional force shall be equal to 3 times the weight of the *BDM/CDM/PDS* but not less than 50 N. The *BDM/CDM/PDS* and its associated mounting means shall remain undamaged during the test.

Compliance shall be demonstrated either by test according to 5.2.2.5 or calculation or simulation.

5.2.2.6 Handles and manual control securement test (*type test*)

Handles and manual controls shall be tested by manual test and by trying to remove the handle, knob, grip or lever by applying for 1 min an axial force as shown in Table 26.

Table 26 – Pull values for handles and manual control securement

	Axial pull unlikely N			**Axial pull likely** N		
Intended for operation by	Fingers	1 hand	2 hands	Fingers	1 hand	2 hands
Operating means of *components* [a]	15	100	200	30	150	300
Other	20	150	300	50	200	450

[a] Handles, knobs, grips, levers and the like intended to operate *components*, such as valve controls, electrical switch handles etc.

During the tests from Table 26, the handles, knobs, grips levers and the like shall remain fixed to the *BDM/CDM/PDS* as intended.

5.2.2.7 Strain relief test (type test)

5.2.2.7.1 Performing the test

Each strain relief in 4.12.6 and cord anchorage in 4.11.10.2.2 of a *BDM/CDM* shall be tested with each combination of cord or cable and bushing. The cord or cable

a) is pushed one time into the *BDM/CDM* manually, as far as possible,
b) is subjected 25 times to a steady pull test with the value shown in Table 27, applied for 1 s each time in the least favourable direction, and
c) is subjected for 1 min to a rotational torque test with the value shown in Table 27 as close as possible to the external end of the cord strain relief or bushing.

Table 27 – Values for physical tests on strain relief of *enclosure*

Mass of *BDM/CDM* kg	Force for steady pull test N	Torque for torque test Nm
≤ 1	30	0,10
> 1 to ≤ 4	60	0,25
> 4	100	0,35

5.2.2.7.2 Acceptance criteria

1) The cord or cable shall not have been damaged.
2) The cord or cable shall not have been displaced longitudinally by more than 2 mm.
3) There shall be no signs of strain at the point where the strain relief clamps the cord or cable.
4) *Clearance* and *creepage distance*s according to 4.4.7.4 and 4.4.7.5 shall not have been reduced below the applicable values.
5) The cord or cable shall pass the AC or DC voltage test of 5.2.3.4 as follows:
   a) for BDM/CDM/PDS with a PE conductor,
      i) the test is made between the *PE conductor* and the phase and neutral conductors joined together, with the test voltage for *basic protection*, and
      ii) the continuity between conductive *accessible parts* and the *PE conductor* shall be tested according to 5.2.3.11.2;
   b) for BDM/CDM/PDS without a PE conductor, the test is made between conductive accessible parts of the BDM/CDM/PDS and the phase and neutral conductors joined together, with the test voltage for enhanced protection.

5.2.2.8 Isolating means and *interlock* integrity test (*type test*)

5.2.2.8.1 Performing the isolating means test

When required in 4.4.10.1 and 4.4.10.2.1.1, all isolating means shall be subjected to 1 000 no load mechanical opening and closing operations. After every 100 operations, it shall be confirmed that all *interlock* functions are operative by attempting to open any doors, operate electrical circuits, or any other operation that is meant to be prevented by the *interlock*ing arrangement.

Where drawout *components* are used, it shall be determined that

a) the device cannot be inserted in any condition of misalignment that will allow operation of the device while impairing the effectiveness of the *interlock*ing arrangement, and
b) the device cannot be withdrawn in the closed position.

In the case of a drawout *component*, one operation shall consist of a cycle of withdrawing from a fully engaged position to the isolated position and then returning to the fully engaged position.

The effort required to perform the 1 000th operation shall be essentially the same as that required to perform the first operation. Upon the completion of the 1 000 operations, the sample shall be in substantially the same mechanical condition as at the beginning of the test.

5.2.2.8.2 Performing drawout contactor test

A drawout contactor that is not utilized as the *BDM/CDM/PDS* isolation means shall be inserted and withdrawn a total of 50 times. The effort required to perform the 50th operation shall be essentially the same as that required to perform the first operation. Upon the completion of the 50 operations, the sample shall be in substantially the same mechanical condition as at the beginning of the test.

5.2.2.8.3 Performing mechanical *interlock* test

If isolation means are not provided, mechanical *interlock*s shall be tested 10 times by attempting to gain access to all high-voltage compartments, operate electrical circuits, or any other operation that is meant to be prevented by the *interlock*ing arrangement. After the test, it shall be confirmed that

a) all *interlock* functions are fully operative, and

b) *interlock*s are in substantially the same mechanical condition as the beginning of the test.

5.2.2.9 Acoustic noise test (*type test*)

When required in 4.10.2, compliance is checked by *visual inspection* in 5.2.1, measurement or calculation of the maximum acoustic noise level in accordance with ISO 3746:2010 or ISO 9614-1:1993 as refered in IEC 60034-9.

5.2.3 Electrical tests

5.2.3.1 General

The electrical tests described in 5.2.3.2 to 5.2.3.5 are applicable to *basic insulation*, *supplementary insulation, double insulation* and *reinforced insulation* when required by 4.4.7.4 (*clearance*) and 4.4.7.8 (*solid insulation*).

Before performing these tests as *type tests* or *sample tests*, preconditioning according to 5.2.6.3.2 and 5.2.6.3.4 is required.

When performing electrical and preconditioning tests, the preferred procedure is to test the entire *BDM/CDM/PDS*; however, it is acceptable to test the *components* or sub-assemblies providing *basic insulation*, *supplementary insulation, double insulation* and *reinforced insulation* separately. When *components* or sub-assemblies are tested separately, the test conditions shall simulate the least favourable conditions occurring inside the *BDM/CDM/PDS* at the place of *installation*.

When these tests are performed as part of acceptance criteria, then no preconditioning for tests is required.

5.2.3.2 *Impulse withstand voltage* test (*type test, sample test*)

The *impulse withstand voltage* test is performed with a voltage having a 1,2/50 μs waveform (see IEC 61180:2016, 7.1 and 7.2) and is intended to simulate overvoltages of atmospheric origin. It also covers overvoltages due to switching of equipment. See Table 28 for conditions of the *impulse withstand voltage* test.

Tests on *clearance*s smaller than required by 4.4.7.4 and tests on *solid insulation* required by 4.4.7.8 are performed as *type tests* using appropriate voltages from Table 29 or Table 30.

Tests on *components* and devices for *enhanced protection* are performed as a *type test* and a *sample test* before they are assembled into the *BDM/CDM/PDS*, using the *impulse withstand voltage*s listed in column 3 or column 5 of Table 29 or Table 30, as appropriate.

To ensure that *surge protective devices* (see 4.4.7.2.3, 4.4.7.2.4, 4.4.7.3) are able to reduce the overvoltage in 4.4.7.2.1, the values of column 2 or column 4 in Table 29 or Table 30, as appropriate, are applied to the *BDM/CDM/PDS* as a *type test*. The measured peak voltage shall not exceed the next lower voltage value of the same column of that table.

If it is necessary to test a *clearance* that has been designed according to 4.4.7.4.3 for altitudes between 2 000 m and 20 000 m (using IEC 60664-1:2020, Table A.2, which is reproduced as Table E.1) or test a *clearance* designed according to 4.4.7.4.3 for frequencies above 30 kHz, the appropriate test voltage may be determined from this *clearance*, using Table E.2 in reverse.

Table 28 – *Impulse withstand voltage* test

<table>
<tr><th>Subject</th><th colspan="3">Test conditions</th></tr>
<tr><td>Test reference</td><td colspan="3">IEC 61180:2016, Clause 7 and Annex C; IEC 60664-1:2020, 6.4.4</td></tr>
<tr><td>Requirement reference</td><td colspan="3">Acc. to 4.4.3.2, 4.4.5.4, 4.4.7, 4.4.7.4.4, 4.4.7.10.2, 4.4.7.10.3, 4.4.7.8.3, 5.2.2.1</td></tr>
<tr><td>Testing of</td><td colspan="2">Clearances, solid insulation, components and sub-assemblies during type test.</td><td>Transient overvoltage reduction</td></tr>
<tr><td rowspan="2">Preconditioning</td><td colspan="2">For type test and sample test, solid insulation and components bridging basic protection, fault protection or enhanced protection shall be preconditioned once according to 5.2.3.1.
No preconditioning is required for testing clearance.</td><td rowspan="2">None</td></tr>
<tr><td colspan="2">Live parts belonging to the same circuit shall be connected together.</td></tr>
<tr><td>Impulse withstand voltage shall be applied between:</td><td colspan="2">1) circuit under test and the surroundings; and
2) circuits to be tested.</td><td>The parts for which reduction of impulse withstand voltage due to circuit characteristics or due to SPD shall be verified.</td></tr>
<tr><td>Initial measurement</td><td colspan="3">None.</td></tr>
<tr><td>Test equipment</td><td colspan="3">An impulse generator with an output impedance not higher than 2 Ω shall be used, where the output impedance is specified by dividing the open-circuit peak output voltage by the peak current measured into short-circuits irrespective of current waveform.</td></tr>
<tr><td>Alternative test equipment</td><td colspan="2">An impulse generator with an output impedance of not higher than 500 Ω is permitted to be used, if the impulse withstand voltage is verified to show full crest value at the object under test.</td><td>None</td></tr>
<tr><td>Alternative test</td><td colspan="2">See 5.2.3.3.</td><td>None</td></tr>
<tr><td>Power</td><td colspan="2">is not applied to the circuits under test.</td><td>may be necessary</td></tr>
<tr><td>Type of protection</td><td>Basic protection/ fault protection</td><td>Enhanced protection</td><td>--</td></tr>
<tr><td rowspan="3">Measurement and verification</td><td>Clearances smaller than required by 4.4.7.4.4 in case of homogeneous field conditions;</td><td>--</td><td>Impulse withstand voltage rating reduced by surge protective device or by circuit characteristics</td></tr>
<tr><td>Solid insulation,
basic protection or fault protection;</td><td>Solid insulation
enhanced protection;</td><td>--</td></tr>
<tr><td>Components and sub-assemblies bridging basic protection or fault protection.</td><td>Components and devices for enhanced protection.</td><td>--</td></tr>
<tr><td>Quantity of pulses</td><td colspan="3">Three pulses of each polarity with an interval of ≥ 1 s, set to a minimum open-circuit peak voltage according to:</td></tr>
<tr><td>Appropriate test voltage</td><td>Column 2 or column 4 of Table 29; column 2 or column 4 of Table 30</td><td>Column 3 or column 5 of Table 29; column 3 or column 5 of Table 30</td><td>Column 2 or column 4 of Table 29; column 2 or column 4 of Table 30</td></tr>
<tr><td rowspan="2">Altitude correction</td><td colspan="3">When the test is carried out on a clearance at an altitude less than 2 000 m, the test voltage shall be increased according to IEC 60664-1:2020, Table F.6, which is reproduced as Table E.2 in this document.</td></tr>
<tr><td colspan="3">The altitude correction factor does not apply to impulse withstand voltage testing on solid insulation according to IEC 60664-1:2020, 6.4.4.1.</td></tr>
</table>

The *impulse withstand voltage* test is successfully passed if no puncture of *insulation*, flashover or sparkover occurs. In the case of *components* and devices which use *solid insulation* for *enhanced protection*, a subsequent partial discharge test (see 5.2.3.5) shall also be passed when required by 4.4.7.10.3.

Alternatively for *high-voltage BDM/CDM/PDS*, the *impulse withstand voltage* test is successfully passed if

a) 3 consecutive impulses for each polarity have been applied and
   - no disruptive discharge occurs, or
   - one discharge occurs in the self-restoring part of insulation, and then nine additional impulses have been applied with no disruptive discharge occurring, or

b) 15 consecutive impulses for each polarity have been applied and
   - the number of disruptive discharges on self-restoring insulation does not exceed two for each series, and
   - no disruptive discharge on non-self-restoring insulation occurs.

Table 29 – *Impulse withstand voltage* test voltage for *low-voltage BDM/CDM/PDS*

Column 1	**2**	**3**	**4**	**5**
***System voltage* (see 4.4.7.1.7)**	***Impulse withstand voltage* for *insulation* between circuits connected to *non-mains supply* and their *surroundings* according to overvoltage category II**		***Impulse withstand voltage* for *insulation* between circuits connected to *mains supply* and their *surroundings* according to overvoltage category III**	
V	**Basic or supplementary** V	**Reinforced** V	**Basic or supplementary** V	**Reinforced** V
≤ 50	500	800	800	1 500
100	800	1 500	1 500	2 500
150	1 500	2 500	2 500	4 000
300	2 500	4 000	4 000	6 000
600	4 000	6 000	6 000	8 000
1 000	6 000	8 000	8 000	12 000
-	Interpolation is permitted		Interpolation is not permitted	

NOTE 1 Test voltages for overvoltage categories I and III (col. 2 and 3) can be derived in a similar way from Table 6.

NOTE 2 Test voltages for overvoltage categories II and IV (col. 4 and 5) can be derived in a similar way from Table 6.

Table 30 – *Impulse withstand voltage* test voltage for *high-voltage BDM/CDM/PDS*

Column 1	2	3	4	5
***System voltage* (see 4.4.7.2.1)**	***Impulse withstand voltage* for *insulation* between circuits and their *surroundings* according to overvoltage category III**		***Impulse withstand voltage* for *insulation* between circuits and their *surroundings* according to overvoltage category IV**	
V	***Basic* or *supplementary*** V	***Reinforced*** V	***Basic* or *supplementary*** V	***Reinforced*** V
> 1 000	8 000	12 800	12 000	19 200
3 600	20 000	32 000	40 000	64 000
7 200	40 000	64 000	60 000	96 000
12 000	60 000	96 000	75 000	120 000
17 500	75 000	120 000	95 000	152 000
24 000	95 000	152 000	125 000	200 000
36 000	125 000	200 000	145 000	232 000
Interpolation is permitted.				
NOTE Test voltages for overvoltage categories I and II can be derived in a similar way from Table 6.				

5.2.3.3 Alternative to *impulse withstand voltage* test (*type test, sample test*)

If permitted in Table 28, a modified AC or DC voltage test according to 5.2.3.4 may be used as an alternative method to the *impulse withstand voltage* test of 5.2.3.2.

For an AC voltage test, the peak value of the AC test voltage shall be equal to the *impulse withstand voltage* test voltage of Table 29 or Table 30, as appropriate and applied for three cycles of the AC test voltage.

For a DC voltage test, the mean value of the DC test voltage shall be equal to the *impulse withstand voltage* test voltage of Table 29 or Table 30, as appropriate, and applied 3 times for 10 ms in each polarity.

The ramp time shall comply with Table 34.

See IEC 60664-1:2020, 6.2.2.1.3, for further information.

The altitude correction according to Table 28 applies.

5.2.3.4 AC or DC voltage test (*type test, routine test*)

5.2.3.4.1 Purpose of test

The *type test* is used to verify that the *clearance*s and *solid insulation* of *components* and assembled *BDM/CDM/PDS* have adequate dielectric strength to resist *temporary overvoltage* conditions.

The *routine test* is performed to verify that *clearance*s have not been reduced during the manufacturing process.

NOTE In the USA, the AC or DC voltage test is required as a *type test*, not as a *routine test*.

5.2.3.4.2 Value and type of test voltage

The values of the test voltage are determined from column 2 or 3 of Table 31, Table 32, or Table 33, depending upon whether the circuit under test is connected to *low-voltage mains supply*, *high-voltage mains supply*, or *non-mains supply*.

The test voltage from column 2 is used for testing circuits with *basic protection*.

Between circuits with *enhanced protection* (*double insulation* or *reinforced insulation*), the test voltage of column 3 shall be applied for *type tests*. For *routine tests* between circuits with *enhanced protection*, the values from column 2 shall be applied to prevent damage to the *solid insulation* by partial discharge.

The values of column 3 shall apply to *BDM/CDM/PDS* with *enhanced protection* according to 4.4.5.

For circuits connected to *non-mains supply* where *temporary overvoltage*s are present, the test voltage shall be as follows:

- for performing *type tests* of circuits with *basic protection*, and for all *routine testing*: the *temporary overvoltage* (AC RMS or DC) as determined in 4.4.7.2.4;
- for performing *type tests* of circuits with *enhanced protection*, and between circuits and accessible surfaces (non-conductive or conductive but not connected to protective earth, *protective class II* according to 4.4.6.3): 1,6 times the *temporary overvoltage* (AC RMS or DC) as determined in 4.4.7.2.4.

For *non-mains* circuits, where *temporary overvoltages* are not present, the test voltages are determined from Table 33, based on the *working voltage*.

The voltage test shall be performed with a sinusoidal voltage at 50 Hz or 60 Hz. If the circuit contains capacitors, the test may be performed with a DC voltage of a value equal to the peak value of the specified AC voltage.

For a circuit that is galvanically connected to both *mains supply* and *non-mains supply*, the test voltages are determined by considering the worst-case result of using the *mains supply system voltage* determined from column 2 or 3 of Table 31, and the result of using the *non-mains supply* recurring peak *working voltage* determined from Table 33.

Table 31 – AC or DC test voltage for circuits connected directly to *low-voltage mains supply*

Column 1 ***System voltage* for *temporary overvoltage*** **(see 4.4.7.1.7 a))**	**2** **Voltage for *type tests* of circuits with *basic protection*, and for all *routine testing***		**3** **Voltage for *type tests* of circuits with *enhanced protection*, and between circuits and accessible surfaces (non-conductive or conductive but not connected to protective earth, *protective class II* according to 4.4.6.3)**	
V	**AC RMS** [a] V	**DC** V	**AC RMS** V	**DC** V
≤ 50	1 250	1 770	2 500	3 540
100	1 300	1 840	2 600	3 680
150	1 350	1 910	2 700	3 820
300	1 500	2 120	3 000	4 240
600	1 800	2 550	3 600	5 090
1 000	2 200	3 110	4 400	6 220

Interpolation is permitted.

It is recommended to use test equipment as described in IEC 61180:2016.

[a] Corresponding to 1 200 V + *system voltage*.

Table 32 – AC or DC test voltage for circuits connected directly to *high-voltage mains supply*

Column 1 **Phase to phase *System voltage*** **(see 4.4.7.1.7 b))**	**2** **Voltage for *type tests* of circuits with *basic protection*, and for all *routine testing***		**3** **Voltage for *type tests* of circuits with *enhanced protection*, and between circuits and accessible surfaces (non-conductive or conductive but not connected to protective earth, *protective class II* according to 4.4.6.3)**	
V	**AC RMS** [a] V	**DC** V	**AC RMS** V	**DC** V
> 1 000	3 000	4 250	4 800	6 800
3 600	10 000	14 150	16 000	22 650
7 200	20 000	28 300	32 000	45 300
12 000	28 000	39 600	44 800	63 350
17 500	38 000	53 700	60 800	85 900
24 000	50 000	70 700	80 000	113 100
36 000	70 000	99 000	112 000	158 400

Interpolation is permitted.

It is recommended to use test equipment as described in IEC 61180:2016.

[a] Values from IEC 60071-1:2019, Table 2.

Table 33 – AC or DC test voltage for circuits connected to *non-mains supply* without *temporary overvoltage*s

Column 1 *Working voltage* (recurring peak) (see 4.4.7.1.7.2)	2 Voltage for *type tests* of circuits with *basic protection*, and for all *routine testing*		3 Voltage for *type tests* of circuits with *enhanced protection,* and between circuits and accessible surfaces (non-conductive or conductive but not connected to protective earth, *protective class II* according to 4.4.6.3)	
V	AC RMS V	DC V	AC RMS V	DC V
≤ 71	80	110	160	220
141	160	225	320	450
212	240	340	480	680
330	380	530	760	1 100
440	500	700	1 000	1 400
600	680	960	1 400	1 900
1 000	1 100	1 600	2 200	3 200
1 600	1 800	2 600	2 900	4 200
2 300	2 600	3 700	4 200	5 900
3 000	3 400	4 800	5 400	7 700
4 600	5 200	7 400	8 300	11 800
7 600	8 500	12 000	14 000	19 000
16 000	18 000	26 000	29 000	42 000
23 000	26 000	37 000	42 000	59 000
30 000	34 000	48 000	54 000	77 000
38 000	43 000	61 000	69 000	98 000
50 000	57 000	80 000	91 000	130 000
60 000	70 000	99 000	109 000	154 000
Interpolation is permitted. It is recommended to use test equipment as described in IEC 61180:2016. NOTE Test voltages in this table are based upon 80 % of the withstand voltage for the corresponding *clearance* of Table 8 as provided by IEC 60664-1:2020, Table A.1.				

5.2.3.4.3 Additional test considerations

Protective devices designed to reduce *impulse withstand voltage*s on the circuits under test (see 4.4.7.2.3 and 4.4.7.2.4), and circuits belonging to monitoring or protection circuits, not designed to sustain the test overvoltage for the duration of the test, shall be disconnected in order to avoid damage and to ensure that the test voltage can be applied without a false indication of failure.

Wherever practicable, individual *components* forming part of the *insulation* under test, for example interference suppression capacitors, should not be disconnected or bridged before the test. In this case, it is recommended to use the DC test voltage according to 5.2.3.4.2.

Where testing is not possible in the assembled *BDM/CDM/PDS* due to a low impedance of the *protective impedances* or *SPD* not designed to sustain the test voltage for the duration of the test, the connection to the *protective impedances* or *SPD* shall be opened before testing. In the latter case, the connection shall be carefully restored after the voltage test.

Protective impedances according to 4.4.5.4 shall either be included in the testing or the connection to the protectively separated part of the circuit shall be opened before testing. In the latter case, the connection shall be carefully restored after the voltage test in order to avoid any damage to the *insulation*.

5.2.3.4.4 Performing the voltage test

The test shall be applied as follows, according to Figure 14.

a) Test (1) between conductive *accessible part* (connected to earth) and each circuit sequentially (except *DVC As* circuits). Test voltage according to Table 31, Table 32 or Table 33, column 2, corresponding to voltage of considered circuit under test.

   Test (2) between accessible surface (non conductive or conductive but not connected to earth) and each circuit sequentially (except *DVC As* circuits). Test voltage according to Table 31, Table 32 or Table 33, column 3 (for *type test*) or column 2 (for *routine test*), corresponding to voltage of considered circuit under test.

b) Test between each considered circuit sequentially and the other adjacent circuits connected together (except for between DVC As circuits). Test voltage according to Table 31, Table 32 or Table 33, column 2, corresponding to voltage of considered circuit under test.

c) Test between DVC As circuit and each adjacent circuit sequentially. Test voltage according to Table 31, Table 32 or Table 33, column 3 (for type test) or column 2 (for routine test), corresponding to the circuit with the higher voltage. Either the adjacent circuit or the DVC As circuit may be earthed for this test. It is necessary to test basic insulation between DVC As and PELV circuits or SELV circuits, but it is not necessary to test functional insulation between adjacent PELV circuits or adjacent SELV circuits.

Because *DVC As* and *PELV* circuits or *SELV* circuits and circuits of *DVC C* and *DVC D* are typically separated from chassis (earth) by *basic insulation*, it is typically impossible to test *double insulation* or *reinforced insulation* separating *DVC As* and *PELV* circuits or *SELV* circuits from *DVC C* and *DVC D* circuits in a fully-assembled *PDS* without overstressing the *basic insulation*. Because of this, it may be necessary to disassemble the *PDS*, or it may not be possible to perform *type tests* of protective *insulation* at voltages according to column 3 of Table 31 to Table 33. In these cases, the *type test* of *insulation* used for *enhanced protection* shall be performed at voltages according to column 2 of the appropriate table.

NOTE Test of double insulation or reinforced insulation is done on the component separately.

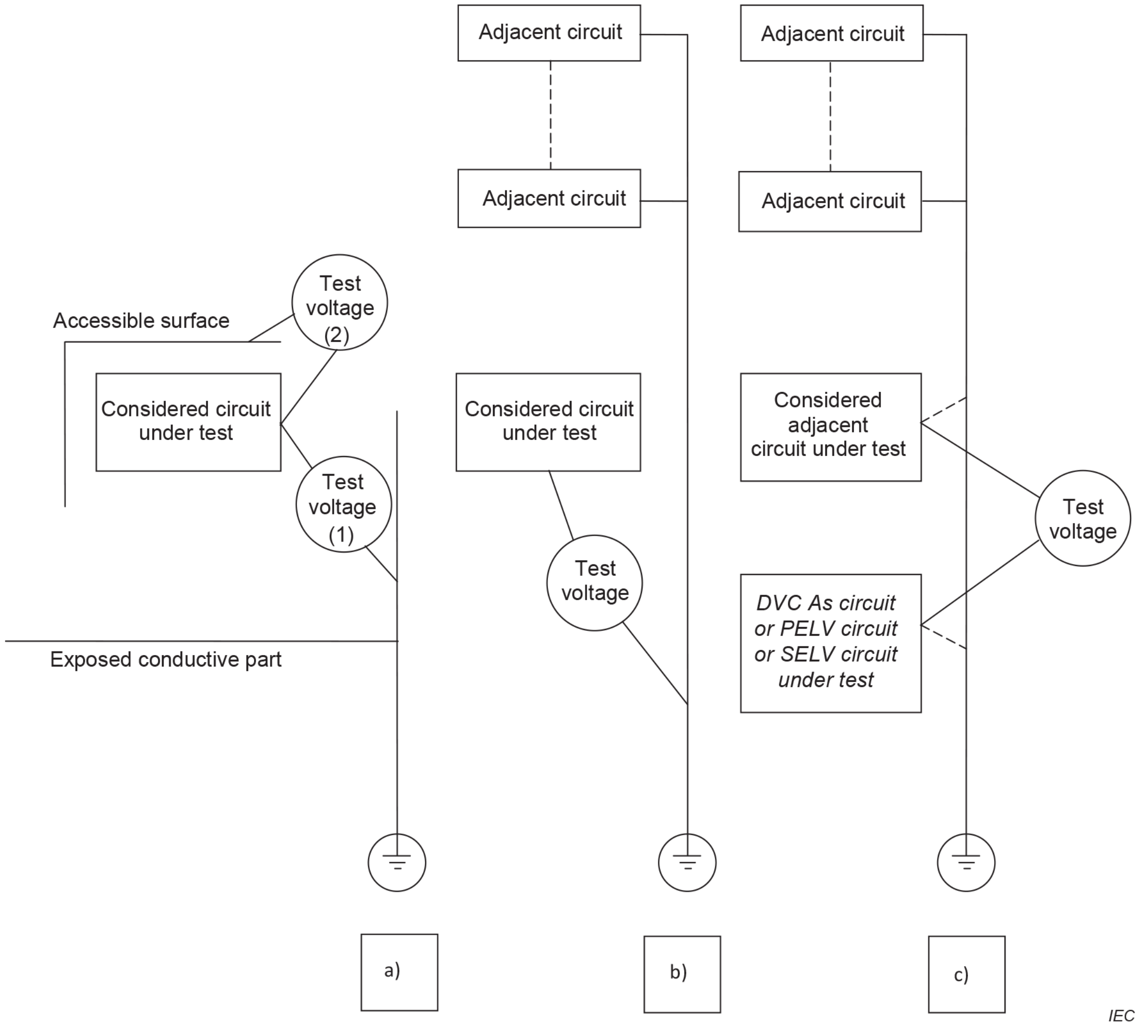


Figure 14 – Voltage test procedures

The tests shall be performed with the doors of the *enclosure* closed and all *enclosure covers* in place.

When the circuit is electrically connected to conductive *accessible parts*, the voltage test is not relevant, and may be omitted.

To create a continuous circuit for the voltage test on the *PDS*, terminals, open contacts on switches and semiconductor devices, etc. shall be bridged where necessary. Before testing, semiconductor devices and other vulnerable *components* within a circuit may be disconnected and/or their terminals bridged to avoid damage occurring to them during the test.

Where the *BDM/CDM/PDS* is covered totally or partly by a non-conductive *accessible surface*, a conductive foil to which the test voltage is applied shall be wrapped around this surface for testing. In this case, the *insulation* test between a circuit and non-conductive accessible surface may be performed as a *sample test* instead of a *routine test*.

The applied output potential shall be measured and monitored throughout the test.

Protective screens according to 4.4.4.7 shall remain connected to conductive *accessible parts* during the voltage test.

Routine test of the assembled *BDM/CDM/PDS* is not required if

- *routine test* of all sub-assemblies related to the *insulation system* of the *BDM/CDM/PDS* is performed,
- it can be demonstrated that the final assembly will not compromise the *insulation system*, and
- the *type test* of the fully-assembled *BDM/CDM/PDS* was performed successfully.

5.2.3.4.5 Duration of the AC or DC voltage test

For *BDM/CDM/PDS*, the test parameters are listed in Table 34 for *type test* and for *routine test*.

Table 34 – Parameter for *BDM/CDM/PDS* AC or DC voltage test

BDM/CDM/PDS	Ramp time up and down	Duration of full voltage *type test* and *routine test*	Test voltage
Low-voltage	≥ 1 s	60 s [a]	Table 31 or Table 33
High-voltage	≥ 5 s	5 s [a]	Table 32 [b]

[a] For *routine test* only, the test duration may be reduced to 1 s.

[b] If the voltage test has already been successfully performed at 100 % test voltage, and is required as acceptance criteria of another *type test*, the voltage may be de-rated to 80 % of the original test voltage.

5.2.3.4.6 Verification of the AC or DC voltage test

The test is successfully passed if no *electrical breakdown* occurs during the test.

5.2.3.5 Partial discharge test (*type test*, *sample test*)

The partial discharge test shall confirm that the *solid insulation* (see 4.4.7.8) used in *components* and sub-assemblies for *enhanced protection* of electrical circuits remains partial-discharge-free within the specified voltage range (see Table 35).

NOTE In the USA, partial discharge tests are not required.

This test shall be performed as a *type test* and a *sample test* as specified in 4.4.7.10. It may be omitted for insulating materials which are not degraded by partial discharge, for example ceramics or glass.

The partial discharge inception and extinction voltage are influenced by climatic factors (e.g. temperature and moisture), equipment self heating, and manufacturing tolerance. These influencing variables can be significant under certain conditions and shall therefore be taken into account during performing a *type test*.

Table 35 – Partial discharge test

Subject	Test conditions
Test reference	IEC 60664-1:2020, 6.4.6
Requirement reference	4.4.7.8
Preconditioning	Preconditioning according to 5.2.3.1 shall be carried out for *type test* and *sample test*. The *impulse withstand voltage* test 5.2.3.2 shall be performed as preconditioning before performing the partial discharge. *Live part*s belonging to the same circuit shall be connected together. It is advisable that the partial discharge test is performed before inserting the *components* or devices into the *BDM/CDM/PDS* because partial discharge testing is not normally possible when the *BDM/CDM/PDS* is assembled.
Initial measurement	According to specification of *component* or device.
Test equipment	Calibrated charge measuring device or radio interference meter without weighting filters.
Test circuit Test voltage Test method	IEC 60664-1:2020, Clause C.1 The peak value of AC 50 Hz or 60 Hz IEC 60664-1:2020, 6.4.6.1: F_1 = 1,2; F_2, F_3 = 1,25. Test procedure IEC 60664-1:2020, 6.4.6.3
Calibration of test equipment	IEC 60664-1:2020, Clause C.4
Measurement and verification	Starting from a voltage below the rated partial discharge test voltage U_{PD} [a], the voltage shall be linearly increased to 1,875 times U_{PD} and held for a maximum time of 5 s (see Figure 15). The voltage shall then be linearly decreased to 1,5 times U_{PD} (±5 %) and held for a maximum time of 15 s, during which the partial discharge is measured.
NOTE 1 Partial discharge testing of *solid insulation* with a DC *working voltage* according to A.5.4 can be omitted. NOTE 2 While the reference standard is limited to *low-voltage BDM/CDM/PDS*, this test procedure is extended to *high-voltage BDM/CDM/PDS* covered in this document.	
[a] The rated partial discharge test voltage U_{PD} is the recurring peak voltage measured across the *insulation*.	

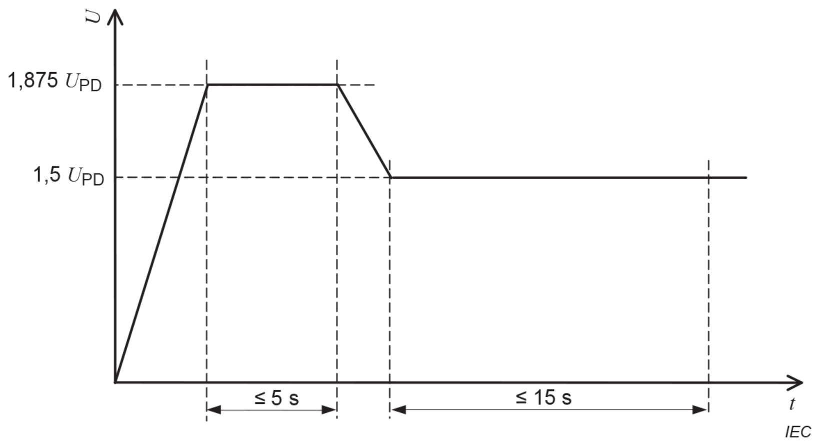


Figure 15 – Partial discharge test procedure

The test shall be considered to have been successfully passed if the partial discharge is less than 10 pC during the measurement period.

Values less than 10 pC are required for an *insulation system* that through its construction could be damaged due to air void when exposed to the voltage stress (for example cast resin, potting, moulding, triple insulated wire, etc.).

Corona discharges in air do not have a defined acceptance criterion.

5.2.3.6 *Protective impedance* test (*type test, routine test*)

A *type test* shall be performed to verify that the current through a *protective impedance* under normal operating or *single-fault conditions* does not exceed the values given in 4.4.5.4.

NOTE 1 In the USA and Canada, the *protective impedance* test is required as a *type test*, not as a *routine test*.

The test shall be performed using the circuit of IEC 60990:2016, Figure 4 (see Figure L.1), or by measuring the current through the *protective impedance* to *protective earth*.

NOTE 2 IEC 60990 states that the use of a single network for the measurement of AC combined with DC has not been investigated, but no suggestion is made for measurement in such cases.

The value of the *protective impedance* shall be verified as a *routine test*.

NOTE 3 Verification of the value of the *protective impedance* can be performed during the manufacturing process.

5.2.3.7 *Touch current* measurement test (*type test*)

The *touch current* shall be measured to determine if the measures in 4.4.4.3.3 are applicable unless one of the measures in 4.4.4.3.3 a) or b) is used. The *BDM/CDM/PDS* shall be set up in an insulated state without any connection to the earth and shall be operated at rated voltage. Under these conditions, the *touch current* shall be measured between the means of connection for the *PE conductor* and the *PE conductor* itself with the test circuit of IEC 60990:2016, Figure 4 (see Figure L.1).

a) For a *BDM/CDM/PDS* to be connected to an earthed neutral *system*, the neutral of the mains of the test site shall be directly connected to the *PE conductor*.
b) For a *BDM/CDM/PDS* to be connected to an isolated *system* or impedance *system*, the neutral shall be connected through a resistance of 1 kΩ to the *PE conductor* which shall be connected to each input phase in turn. The highest value shall be taken as the definitive result.
c) For a *BDM/CDM/PDS* to be connected to a corner-earthed or high-leg delta *system*, the *PE conductor* shall be connected to each input phase in turn. The highest value shall be taken as the definitive result.
d) For a *BDM/CDM/PDS* with a particular earthing *system*, this *system* shall operate as intended during the test.
e) If a *BDM/CDM/PDS* is intended to be connected to more than one *system* network, each of these different *system* networks (or the worst-case, if that can be determined) shall be used to make the *touch current* measurement.

For *BDM/CDM/PDS* which may be energized from multiple sources of supply, the *touch current* limits in 4.4.4.3.3 apply in all possible intended *installation* configurations and combinations of sources that may be energized at the same time.

This test is performed as a *type test*.

For information, an overview about the measuring test circuit is given in Annex L.

5.2.3.8 Capacitor discharge test (*type test*)

The capacitor discharge time as required by 4.4.9, 4.5.2.2 and 4.11.7 shall be verified by this *type test* and/or by calculation taking into account the relevant tolerances.

The *BDM/CDM/PDS* shall be connected to a supply at the maximum rated voltage and operated until the capacitors under evaluation are fully charged. There shall be no load connected and the *BDM/CDM* shall be in the stopped condition. The voltage across the capacitor shall be monitored before and after removal of the supply power. Timing shall start upon removal of the supply power, and end when the values according to 4.4.9 or 4.5.2.2 (as applicable) are reached.

The voltage monitoring device shall have an input impedance of no less than 1 MΩ.

When the requirements in 4.4.9 and 4.5.2.2 are not met, marking is required according to 6.5.2.

5.2.3.9 Limited power source test (*type test*)

When required by 4.5.3, a limited power source circuit shall be tested as below, with the *BDM/CDM/PDS* operating under normal operating conditions.

In case the limited power source requirement depends on *overcurrent* protective device(s), the device(s) shall be short-circuited.

The open-circuit output voltage shall not exceed the relevant value of Table 15 or Table 16, as applicable.

With the *BDM/CDM/PDS* operating under normal operating conditions, a variable resistive load is connected to the circuit under consideration and adjusted to obtain a level slightly above the limiting current or apparent power level as indicated in Table 15 or Table 16, as applicable. Further adjustment is made, if necessary, to maintain the level of current or apparent power for the time period indicated in Table 15 or Table 16, as applicable.

Single-fault conditions are applied in a regulating network according to 4.2 while operating under the maximum current and power conditions specified above.

The test is passed if, during and after the test period the available current or apparent power, as applicable, does not exceed the limits indicated in Table 15 or Table 16, as applicable.

5.2.3.10 Temperature rise test (*type test*)

This test is intended to ensure that parts and *accessible part*s and surfaces of the *BDM/CDM/PDS* do not exceed the temperature limits specified in 4.6.5 and the *component* manufacturer's temperature limits of safety-relevant parts.

Where possible, the *BDM/CDM/PDS* shall be tested at worst-case conditions of rated power and *BDM/CDM rated output current*, taking derating and cooling control characteristic into account.

To determine whether *BDM/CDM* complies with the temperature test requirements, it is to be operated until thermal stabilization occurs under normal operating conditions as follows:

a) for continuous operation, according to the continuous ratings;
b) for intermittent operation, according to the rated duty cycle; or
c) for short-time operation, for the rated operating time.

Open type BDM/CDM is not required to be tested in an *enclosure* when marked with a *surrounding air temperature* rating.

For *BDM/CDM/PDS* where the amount of heating or cooling is designed to be dependent on temperature (for example, the *BDM/CDM/PDS* contains a fan that has a higher speed at a higher temperature), the temperature measurement shall be performed at the worst case *ambient temperature* condition within the manufacturer's specified operating range.

The *BDM/CDM/PDS* shall be tested with at least 1,2 m of wire attached to each *field wiring terminal*. The wire shall be of the smallest size intended to be connected to the *BDM/CDM/PDS* as specified by the manufacturer for *installation*. When there is only provision for the connection of bus bars to the *BDM/CDM/PDS*, they shall be of the minimum size intended to be connected to the *BDM/CDM/PDS* as specified by the manufacturer, and they shall be at least 1,2 m in length.

The test shall be maintained until thermal stabilization has been reached. That is, when three successive readings, taken at intervals of 10 % of the previously elapsed duration of the test and not less than 10 min intervals, indicate no change in temperature, defined as ±1 °C between any of the three successive readings, with respect to the *ambient temperature*.

If a hazard could be caused by the failure of an *electrical insulation*, the temperature of this *insulation* (other than that of windings) is measured on the outer surface of the *insulation* at a point close to the heat source. If temperatures of windings are measured by the thermocouple method, the thermocouple shall be located on the surface of the winding assuming the hottest part due to surrounding heat emitting *components*. See also footnotes in Table 17.

The maximum temperature attained shall be corrected to the rated *ambient temperature* of the *BDM/CDM/PDS* by adding the difference between the *ambient temperature* during the test and the *BDM/CDM/PDS*'s maximum rated *ambient temperature*.

For testing of intermittent operation or short time operation, the *BDM/CDM/PDS* shall be tested using one of the following methods. The intermittent operation will be cycled

- at the manufacturer's defined "ON/OFF" cycle time repeatedly until the maximum temperature and stability is achieved, which will prove the cycle time selected is safe,
- through one "ON" cycle and then monitor and record the time required until all temperatures return to ambient, which will establish a safe cycle time for the "ON/OFF" cycle, or
- under a manfacturer's defined test cycle which ensures that the intermittent or short time operation specified by the customer is tested to the worst case conditions as is defined by this document.

The *BDM/CDM/PDS* shall be operated at the manufacturer's specific voltage and current for the intermittent operation rating.

The intermittent and short time operations may exceed the 100 % continuous operation levels.

The qualification of an intermittent or short time operation does not remove the requirement to perform the temperature rise test at the 100 % rating of the *BDM/CDM/PDS*.

It is not required to specify a short term or intermittent operating duty cycle.

For compliance,

- no corrected temperature shall exceed the rated temperature of the material or *component* measured, and
- thermal cutout, overload detection functions and devices shall not operate during the test.
- the AC or DC voltage *routine test* according to 5.2.3.4 shall be passed successfully.

5.2.3.11 ***Protective equipotential bonding*** **test (*type test*, *routine test*)**

5.2.3.11.1 General

As required in 4.4.4.2, each conductive *accessible part* under consideration shall withstand the short-circuit *type test* unless analysis shows that the short-circuit withstand capability of the path is adequate, or that the results of one combination are representative of the anticipated results of another combination.

Each conductive *accessible part* under consideration shall be tested separately.

The conductive *accessible part* under consideration shall be selected from amongst those adjacent to AC mains supplied circuits and separated from them by only *basic insulation*.

The *protective equipotential bonding* short circuit withstand test of 5.2.4.4 shall be performed and the disconnection time shall not exceed

- the disconnection time requirement of IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017, Table 41.1 (see Annex Q), for pluggable equipment rated 63 A or less and *permanently connected* equipment rated 32 A or less, and not intended to be connected to the building distribution,
- 5 s for TN-*system*s for *BDM/CDM/PDS* intended to be directly connected to the building distribution, for pluggable equipment rated more than 63 A, and for *permanently connected* equipment rated more than 32 A, or
- 1 s for TT-*system*s for *BDM/CDM/PDS* intended to be directly connected to the building distribution, for pluggable equipment rated more than 63 A, and for *permanently connected* equipment rated more than 32 A.

For *pluggable equipment type A only,* the *protective equipotential bonding* continuity test of 5.2.3.11.2 shall be performed.

5.2.3.11.2 *Protective equipotential bonding* continuity test (*type test, routine test*)

The *protective equipotential bonding* continuity routine test shall be conducted when

- required in 4.4.4.2.2, 5.2.6.2, 5.2.4.4.4, 5.2.2.7.2 or 5.2.3.11.1,
- the *PDS* is assembled at the *installation* location, or
- the continuity of the *protective equipotential bonding* is achieved by a single means only (for example a single conductor or a single fastener).

The test current shall be any convenient value of at least 10 A to allow measurement or calculation of the resistance of the *protective equipotential bonding* means.

NOTE Larger currents used for the continuity test increases the accuracy of the test result, especially with low impedance values, i.e. larger cross sectional areas and/or lower conductor length.

The expected value of the resistance is the result of calculation or simulation considering the length, the cross sectional area and the material of the related *protective equipotential bonding* conductors.

The acceptance criterion is such the resistance measured shall not exceed 110 % of the expected value.

5.2.3.12 Input test *(type test)*

As specified in 6.2.1, the input test shall be performed to determine the maximum input current and input power either by test or calculation or simulation with respect to the worst-case conditions such as, but not limited to,

- input voltage ratings,
- power source characteristics,
- rated output power,
- output current,
- derating characteristics,
- operation mode, and

- cooling control characteristic.

The test shall be conducted for each input power *port*.

These values shall be specified according to 6.2.

5.2.3.13 Thin sheet material test (*type test*)

5.2.3.13.1 General

5.2.3.13 provides requirements for tests of thin sheet materials according to 4.4.7.8.3.

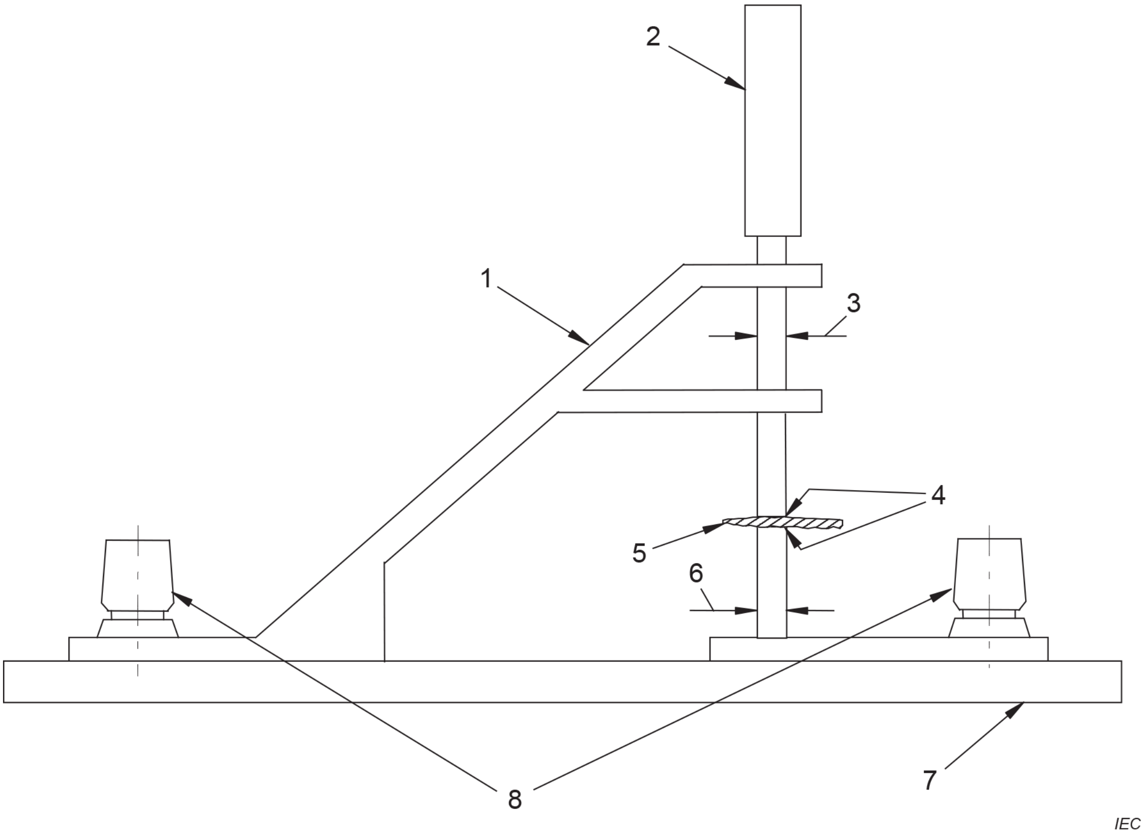
5.2.3.13.2 Test procedure for separable thin sheet material (*type test*)

One layer of the separable material is placed in the electric strength test instrument, as shown in Figure 16, and the test voltage according to the requirements of Table 14 applies.

The test is repeated with more than one layer, if required in Table 14.

In order to avoid an *electrical breakdown* around the edges of the layer of insulating material, the specimen under test shall be sufficiently large that its edges are kept away from the vertical test rods.

This test can be omitted for non-separable material consisting of three or more layers used for *reinforced insulation*, in which case the mandrel test in 5.2.3.13.3 applies.



Key

1	metal frame holding the upper pin in an upright position and allowing it to move up and down	5	specimen (insulating material) under test
2	metal pin having a mass of 100 g	6	Ø 5 mm ± 0,1
3	Ø 5 mm ± 0,1	7	insulating base
4	the edges of the test pin rounded with a radius of 0,5 mm	8	terminals for test voltage

Figure 16 – Electric strength test instrument

5.2.3.13.3 Mandrel test (*type test*, *sample test*)

The test requirements for *reinforced insulation* made of non-separable material consisting of three or more thin insulating sheets are specified below.

NOTE This test is based on IEC 61558-1:2017 and will give the same results.

Three test samples, each individual sample consisting of three or more layers of non-separable thin sheet material forming *reinforced insulation*, are used.

One sample is fixed to the mandrel of the test fixture given in Figure 17. The fixing shall be performed as shown in Figure 18.

Dimensions in millimetres

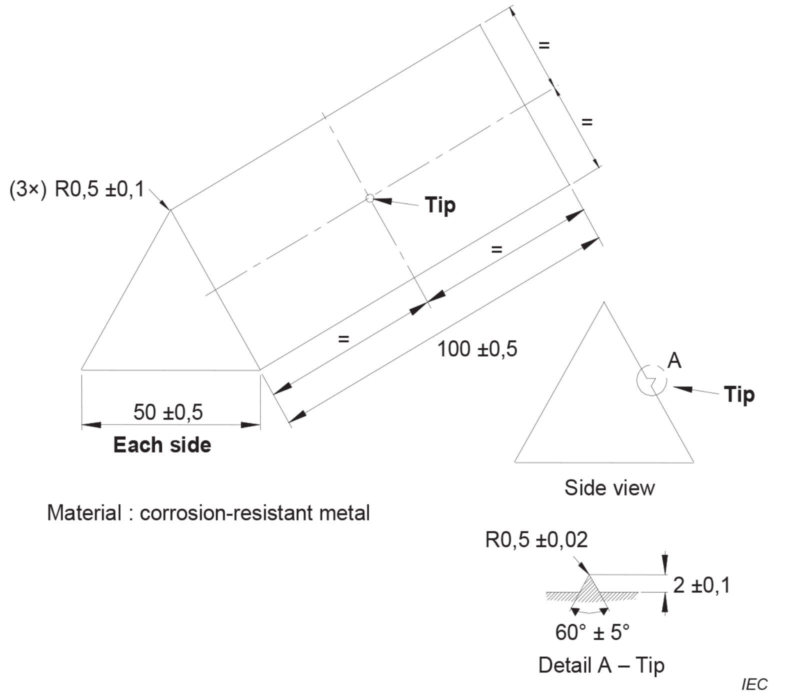


Figure 17 – Mandrel

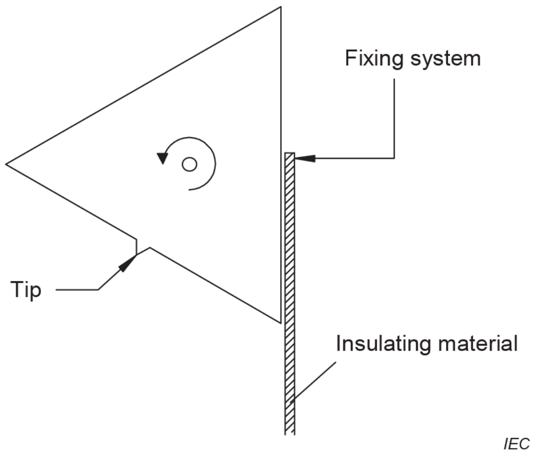
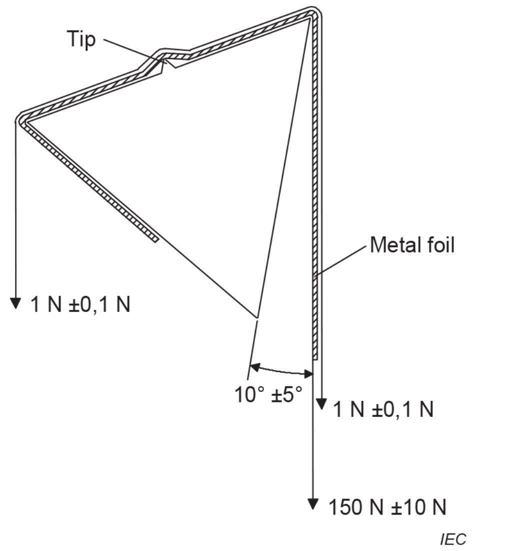


Figure 18 – Initial position of mandrel



The final position of the mandrel is rotated 230° ± 5° from the initial position.

Figure 19 – Final position of mandrel

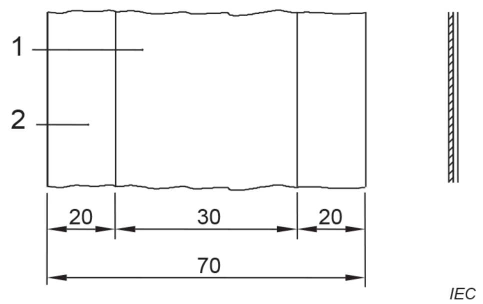
A pull is applied to the free end of the sample, using an appropriate clamping device. The mandrel is rotated

- from the initial position (Figure 18) to the final position (Figure 19) and back, and
- a second time from the initial position to the final position.

If a sample breaks during rotation where it is fixed to the mandrel or to the clamping device, this does not constitute a failure. If a sample breaks at any other place, the test has failed.

After the above test, a sheet of metal foil, 0,035 mm ± 0,005 mm thick, at least 200 mm long, is placed along the surface of the sample, hanging down on each side of the mandrel (see Figure 19). The surface of the foil in contact with the sample shall be conductive, not oxidized or otherwise insulated. The foil is positioned so that its edges are not less than 20 mm from the edges of the sample (see Figure 20). The foil is then tightened by two equal weights, one at each end, using appropriate clamping devices.

Dimensions in millimetres



Key

1 metal foil

2 insulating material

Figure 20 – Position of metal foil on insulating material

While the mandrel is in its final position, and within the 60 s following the final positioning, electric strength tests are applied between the mandrel and the metal foil in accordance with 4.4.7.10.

For *reinforced insulation,* the test voltage U_{test} is

- 100 % of the test voltage specified for the *impulse withstand voltage* test in 4.4.7.10, and
- 150 % of the test voltage specified for the AC or DC voltage test in 4.4.7.10.

Where the peak voltage of U_{test} is less than 7,1 kV, the AC or DC voltage test shall be replaced by an AC voltage test of 5 kV RMS.

The test is repeated on the other two samples.

5.2.3.14 Test procedure for determination of *working voltage* (*type test*)

When required in 4.4.7.1.2, the *working voltage* shall be determined either by calculation, or simulation or by test:

- *working voltage* within circuits;
- *working voltage* against *adjacent circuit*s;
- *working voltage* against PE.

See A.5.1, A.5.2, A.5.3, A.5.4 and A.5.5 for rules for evaluating voltage waveforms.

5.2.3.15 Internal *SPD* monitoring test (*type test*)

A *BDM/CDM* having an internal *SPD* with a monitoring circuit as described in 4.4.7.2.2 shall be subjected to this test. A sample of the *BDM/CDM* shall have each *SPD* device in turn either shorted or open-circuited, whichever is worse case. The *BDM/CDM* shall be connected to its nominal source of supply.

The *BDM/CDM* shall monitor and detect an *SPD* failure and an alarm indication shall be provided.

5.2.3.16 Preconditioning of material (*type test*)

When required in 4.4.7.8.4.2, 4.4.7.8.4.3 and 4.4.7.9, on the same sample the following preconditioning shall be conducted in the prescribed order before performing the *type test*s – the required number of samples is stated in the applicable 4.4.7.8.4.2, 4.4.7.8.4.3 or 4.4.7.9:

1) dry heat test in 5.2.6.3.2;
2) rapid change of temperature test with –25 °C to +125 °C and 50 cycles according to IEC 60664-3:2016, 5.7.4 (test Na of IEC 60068-2-14);
3) damp heat test in 5.2.6.3.4.

5.2.4 *Abnormal operation* and simulated faults tests

5.2.4.1 General

Protection against risk of thermal, electric shock and energy hazards in case of an *abnormal operating condition* of a *component* for a *BDM/CDM/PDS* in combination with its *installation* shall be evaluated by:

a) tests defined in 5.2.4;
b) for *low-voltage BDM/CDM/PDS*, calculation or simulation based on tests as defined in 5.2.4.5 and 5.2.4.10 on a representative model of *BDM/CDM/PDS*, where no damage other than opening of *overcurrent* protective devices has occurred to the test sample;

   NOTE 1 A representative model means a *BDM/CDM/PDS* with similar power elements (for example, *power semiconductor devices*, fuses, circuit breakers, capacitors, *overcurrent* detection, input inductances and output inductances) and circuit topologies as the *PDS* under consideration.

c) for *high-voltage BDM/CDM/PDS*, calculation or simulation based on tests of elements that adequately represent those used in the *BDM/CDM/PDS*. The elements, tests and test conditions shall be selected so that there is sufficient confidence in the test results for them to be transferred (for example, by scaling from lower to higher power) to the *BDM/CDM/PDS* under consideration; or
d) for custom *PDS*, risk and hazard analysis of the intended application, and analysis of the construction characteristics. See 6.3.8 for commissioning information requirements.

   NOTE 2 Custom *PDS* rely on the construction characteristics of the *installation* to provide protection.

Unless specified otherwise, before all *abnormal operation* and simulated fault tests, the test sample shall be mounted, connected, and operated as described in the temperature rise test.

Simulated faults or *abnormal operating conditions* shall be applied one at a time. Faults that are the direct consequence of a simulated fault or *abnormal operating conditions* are considered to be part of that simulated fault or *abnormal operating condition*.

For an *open type BDM/CDM*, the *BDM/CDM* shall be tested in

1) an unventilated solid *enclosure* 1,5 times each of the individual linear dimensions of the *BDM/CDM*,
2) a wire mesh cage 1,5 times each of the individual linear dimensions of the *BDM/CDM*, or
3) an *enclosure* of such size and with such ventilation as described in the documentation provided with the *BDM/CDM*.

For marking, see 6.3.6.1.

The *BDM/CDM/PDS*, and the wire mesh cage (if used) or *enclosure*, shall be earthed according to the requirements of 4.4.4.2.2.

Cheese cloth or surgical cotton shall be placed at all openings, handles, flanges, joints and similar locations on the outside of the *enclosure* and the wire mesh cage (if used) in a manner which will not significantly affect the cooling when the test lasts long enough to have significant temperature rise.

Where the *BDM/CDM/PDS* under test is specified in its installation manual to require external means of protection against faults, these specific means shall be provided for the test.

The individual tests shall be performed until terminated by activation of a protective device or mechanism (internal or external), a *component* failure occurs that interrupts the fault condition, or the temperatures stabilize.

5.2.4.2 Supply voltage, current and frequency

The test conditions of 5.1.5.3 apply.

The open-circuit voltage of the supply shall be 100 % – 105 % of the rated input voltage. The open-circuit voltage may exceed 105 % of the rated input voltage at the request of the manufacturer.

For the short-circuit test, the supply shall be capable of delivering the specified *prospective short-circuit current* from Table 36 at the connection to the *BDM/CDM/PDS*.

Table 36 – *Prospective short-circuit current* for test vs *BDM/CDM* rated input current

***BDM/CDM* rated input current I_o**	***Prospective short-circuit current***	**Power factor (*BDM/CDM* rated for AC input only)**
A	kA	
$I_o \leq 16$	1	0,7 to 0,8
$16 < I_o \leq 63$	3	0,7 to 0,8
$63 < I_o \leq 125$	5	0,7 to 0,8
$125 < I_o \leq 315$	10	0,5 to 0,7
$315 < I_o \leq 630$	18	0,2 to 0,3
$630 < I_o \leq 1\,000$	30	0,2 to 0,3
$1\,000 < I_o \leq 1\,600$	42	0,2 to 0,3
$1\,600 < I_o$	$0,025 \times I_o + 2,5$ [a]	0,2 to 0,3
[a] Or subject to agreement between user and *BDM/CDM* manufacturer.		

The *prospective short-circuit currents* of Table 36 are considered to represent the majority of low voltage situations the *mains supply* or *non-mains supply* can provide. This is also by default the *maximum prospective short-circuit current* to which the *BDM/CDM/PDS* shall be connected unless the manufacturer has specified a higher value. In case the manufacture specifies a higher *maximum prospective short-circuit current* than provided in Table 36, the test shall be performed using the higher *maximum prospective short-circuit current* and the circuit parameters shall be correct for the higher current level tested. The power factor shall be no greater than the level specified in Table 36 for the next higher *prospective short-circuit current* level. If the maximum *short-circuit current* level selected exceeds 42 kA, the power factor shall not be greater than 0,2 to 0,3; however, a lower power factor may be required due to available laboratory circuits.

NOTE Since the *BDM/CDM/PDS* are protected by up-stream *short-circuit protective devices*, it is important to understand the *prospective short-circuit current* of Table 36 as the *conditional short-circuit current* (I_{cc}) of IEC 62477-1:2022, 4.3.2.2.

For the breakdown of *component* test, the supply shall be capable of delivering a *prospective short-circuit current* from Table 36 or the manufacturer's rating, whichever is the higher. However, if the analysis of 4.2 shows that a lower supply *prospective short-circuit current* value will have the same ultimate result, then that lower supply *prospective short-circuit current* is sufficient for the test.

In cases where the manufacturer is specifying I_{cc} with peak current and duration, an oscilloscope or other suitable instrument shall be used to measure the peak input current during the test and duration of the test in 5.2.4.5, 5.2.4.5.2, and 5.2.4.10.

In cases where the manufacturer is specifying I_{cc} with the protective device rated voltage, current, interrupt rating, I_p and I^2t at I_{cc}, the protective device used during test shall be representative of those ratings.

5.2.4.3 Acceptance criteria

As a result of the *abnormal operation* and simulated fault tests, the *BDM/CDM/PDS* shall comply with the following:

a) there shall be no emission of flame, burning particles or molten metal;
b) the cheese cloth or surgical cotton indicator shall not have ignited;
c) the earth connection and *protective equipotential bonding* of the *BDM/CDM/PDS* shall not have opened;
d) *doors* and *covers* shall remain in place;
e) *accessible DVC As circuits* shall not exhibit voltages greater than the time dependent voltages of Table 2, Figure 2, Figure 3 or Figure 4 as applicable during the test;
f) during and after the test, *hazardous live part*s shall not become accessible;
g) *mains supply* and *non-mains supply* input and output conductors shall not get pulled out of their terminal connector;
h) no parts shall be ejected.

The *BDM/CDM/PDS* shall comply with the AC or DC voltage test following the *abnormal operation* tests of 5.2.4.12 and 5.2.4.13. A single sample may be used for multiple tests, in this case the AC or DC voltage test may be conducted following each test or after the final test of the sequence.

The *BDM/CDM/PDS* is not required to be operational after testing and it is possible that the *enclosure* can become deformed.

Overcurrent protection integral to the *BDM/CDM/PDS*, or required to be used with the *BDM/CDM/PDS*, is allowed to open.

Additionally, at the conclusion of

- the phase to phase short-circuit test in 5.2.4.5.2,
- the phase to earth short-circuit test in 5.2.4.5.3, and
- the breakdown of *component* test in 5.2.4.10,

the *BDM/CDM/PDS* shall be operated until one or more of the following ultimate results are obtained:

i) the operation of *electronic power output short-circuit protection circuitry*;
j) the opening of a *short-circuit protective device* (*SCPD*);
k) a steady state temperature is attained after a minimum of 10 min.

5.2.4.4 *Protective equipotential bonding* short-circuit withstand test (*type test*)

5.2.4.4.1 General

As required by 5.2.3.11.1, a short-circuit test shall be performed to ensure that *protective equipotential bonding* has the ability to withstand the *prospective short-circuit current* that it may be subjected to under *single-fault conditions*.

5.2.4.4.2 Test conditions

Unless the circuit analysis according to 4.2 has shown another result, the representative worst case condition is to connect a short-circuit from one of the *mains supply port*s to the conductive *accessible part* under consideration.

The *BDM/CDM/PDS* under test shall be supplied with power and the output power *port* shall be operating as intended in 5.2.4.1 prior to closing the switching means that applies the short-circuit.

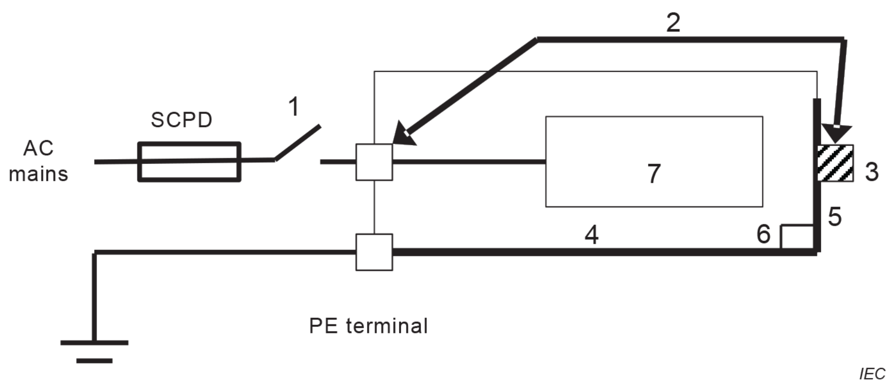
The source shall have a supply voltage and current such that the resulting current through the *protective equipotential bonding* (including the cables and switching device) is equal to the *prospective short-circuit current*.

The *protective equipotential bonding* short-circuit test shall be performed with the *BDM/CDM/PDS* working with light load.

A new sample may be used for each short-circuit test.

5.2.4.4.3 Protective equipotential bonding short-circuit test method

The test current is applied by connecting the conductive *accessible part* under consideration to one of the conductors of the test source circuit through a switching means that shall not limit the short-circuit current. The switch shall be located such that the source is short-circuited through the conductive *accessible part* and its *protective equipotential bonding* path back to the *protective earthing* terminal for the source circuit under consideration. See Figure 21.



Key	
1 switch to power up	5 conductive *accessible part*
2 wire to simulate the fault	6 more than one fastener link
3 connection fault point	7 *hazardous live part*
4 internal *protective equipotential bonding*	

Figure 21 – *Protective equipotential bonding* test set up

5.2.4.4.4 Acceptance criteria

At the conclusion of the test, in addition to acceptance criteria of 5.2.4.3, there shall be no damage to the *protective equipotential bonding* means under test, and the disconnection times of 5.2.3.11.1 shall not be exceeded.

Compliance shall be checked by *visual inspection* in 5.2.1, and if necessary, by the *protective equipotential bonding* continuity test of 5.2.3.11.2.

5.2.4.5 Output short-circuit test (*type test*)

5.2.4.5.1 Load conditions

When required in 4.3.2, the output short-circuit test shall be performed at full load, light load or no load, whichever creates the most severe condition.

5.2.4.5.2 Short-circuit test between phase terminals of output power *port* (*type test*)

As required in 4.3.1, input power *ports* of the *BDM/CDM/PDS* under test shall be provided with conductors of a maximum cross-section permitted by the installation instructions for the input power *ports*.

Output power *ports* shall be provided with conductors of a maximum cross-section permitted by the installation instructions for the output power *ports*. The length of the loop (forth and back) shall be approximately 2 m, unless the size of the *BDM/CDM/PDS* requires a greater length, in which case the length shall be as short as practical to perform the test.

All phase terminals of each output power *ports* tested shall be simultaneously connected together, using an appropriate switching device.

NOTE Terminals connected to the DC link are, for the tests of 5.2.4.5.2 and 5.2.4.5.3, treated as phases.

The *BDM/CDM/PDS* under test shall be supplied with power and the output power *ports* shall be operating as intended prior to closing the switching means that applies to the short-circuit, unless energizing the *BDM/CDM/PDS* with the short-circuit already applied will be more severe.

The testing shall include individual tests of each output power *port* where combinations of two or more terminals, not including earth, on each individual output power *port* are subjected to short-circuit tests on those terminals. Analysis may be used to reduce the number of tests if it is shown that the results of one combination are representative of the anticipated results of another combination.

A new sample may be used for each short-circuit test.

In addition, this test is used to determine the *output short-circuit current* rating of the output power *port* under consideration, in accordance with 4.3.2.3 when internal short-circuit protection is not provided.

When installation instructions of an *open type BDM/CDM* specify external *SCPD* for an output power *port*, the test shall be conducted without the *SCPD* in the output circuit unless the manufacturers instructions specify the *SCPD* shall be provided and located within the same end use *enclosure* as the *BDM/CDM*.

For compliance with 4.3.2.3, an oscilloscope or other suitable instrument shall be used to measure the peak output current during the test, and to measure or calculate the RMS value of the output current.

The peak current, and the highest of the RMS current values are measured or calculated over a time period as follows, are required to be included in the documentation, see 6.2:

a) for AC signals, three cycles of the nominal AC frequency for the output power *port* under consideration, in which case the value shall be stated as the 3-cycle RMS value;
b) for all signals, the duration of the short-circuit from the time the short-circuit is applied, until the time the short-circuit current is interrupted by a protective device or other mechanism, in which case the value stated shall include the RMS value and the time period in seconds;
c) for short-circuit tests that result in a continuous non-zero value, the steady-state RMS value, in which case the value shall be stated as a continuous RMS value.

5.2.4.5.3 Short-circuit test between phase terminals of output power *ports* and earth (*type test*)

For *BDM/CDM/PDS* intended for connection to TN-*system*s or TT-*system*s, the phase to protective earth fault condition shall be evaluated for each phase, one at a time, as a protective earth short-circuit. Short-circuit between phase terminals of output power *ports* and earth is not applicable to *BDM/CDM/PDS* intended only for connection to IT-*system*s.

It is permitted to operate only one test per output if a symmetry per phase can be demonstrated and if the selected phase to be tested represents the most severe case.

See Figure 22, Figure 23 and Figure 24 for examples.

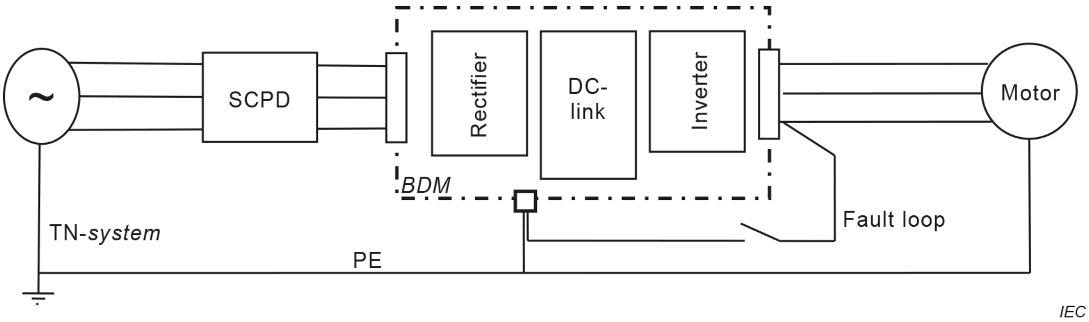


Figure 22 – Example of short-circuit test between *BDM/CDM* motor power *port* and *protective earth* (motor separately earthed)

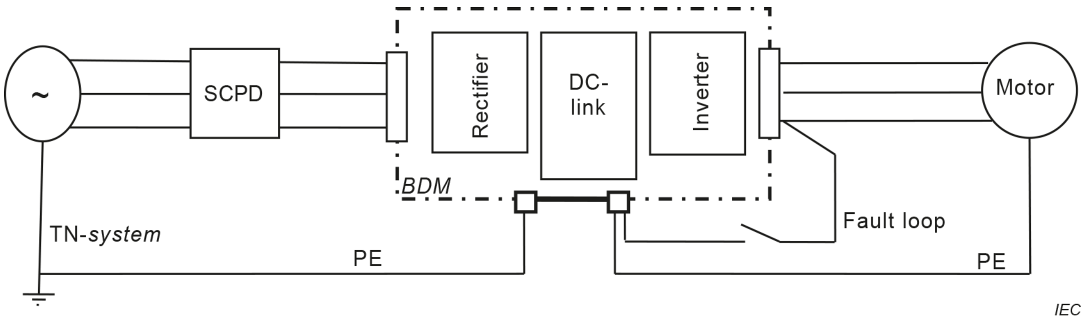


Figure 23 – Example of short-circuit test between *BDM/CDM* motor power *port* and *protective earth* (motor earthed through *BDM/CDM*)

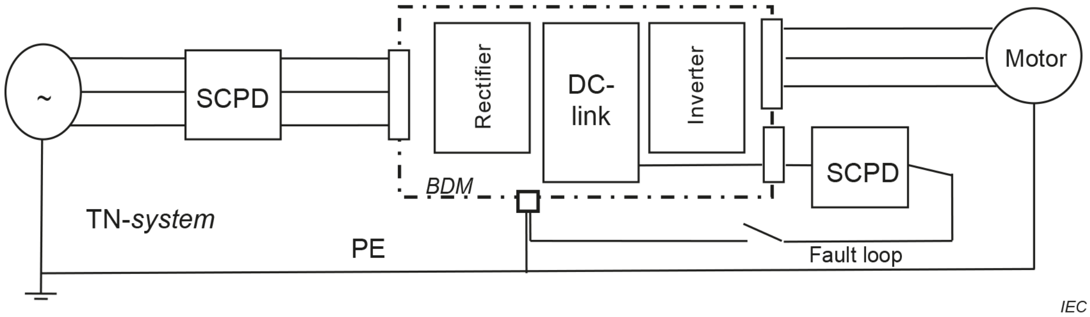


Figure 24 – Example of short-circuit test between *BDM/CDM* DC link power *port* and *protective earth*

5.2.4.6 *Electronic motor overload protection* test (*type test*)

5.2.4.6.1 General requirements

When required in 4.3.5, this test shall demonstrate on one sample of a representative model that the *electronic motor overload protection* operates within the specified limits.

BDM/CDM series that incorporate *electronic motor overload protection* shall comply with test 5.2.4.6.4.

BDM/CDM series that incorporate *electronic motor overload protection* that has *thermal memory retention* shall have one sample of the representative model used complying with the tests in 5.2.4.6.4, 5.2.4.6.5 and 5.2.4.6.6.

BDM/CDM series that incorporate *electronic motor overload protection* that is speed sensitive shall have one sample of the representative model used complying with the tests in 5.2.4.6.4 and 5.2.4.6.7.

5.2.4.6.2 Test set-up

Before performing the tests, the test sample shall be mounted, connected, and operated as described in the temperature rise test and then subjected to the overload condition.

The motor may be simulated by an electrical load consisting of a resistance, reactance, or both such that the load draws the full required RMS current at the *BDM/CDM* motor power *port*.

5.2.4.6.3 Acceptance criteria

The *BDM/CDM/PDS* is required to be operational after testing and shall comply with each requirement of the applicable tests in 5.2.4.6.4, 5.2.4.6.5, 5.2.4.6.6 and 5.2.4.6.7.

5.2.4.6.4 *Electronic motor overload protection* test (*type test*)

For the verification of the functionality of the *electronic motor overload protection*, the test shall be conducted at any current being able to verify the overload tripping condition according to Table 37.

BDM/CDM with fixed overload protection levels shall comply with Table 37 under those fixed settings. *BDM/CDM* with adjustable overload protection levels shall comply with Table 37 under the highest and lowest settings.

The *electronic motor overload protection* in the representative model shall *trip* at any point below the limits from Table 37.

Table 37 – Maximum tripping time for *electronic motor overload protection* test

Multiple of current setting	Maximum tripping time
7,2	20 s
1,5	8 min
1,2	2 h
NOTE 1 The current setting is defined as the rated current of the motor according to its nameplate, which is intended to be protected. NOTE 2 Table 37 covers the minimum requirement for electronic overload relays of class 20 according to IEC 60947-4-1:2018, 8.2.1.5.1.1.	

If the *BDM/CDM* trips at a time equal to or less than the maximum tripping time for a multiple of current setting at a test current lower than the current required by the multiple of current setting, the *BDM/CDM* is considered to comply with that row of Table 37.

BDM/CDM provided with a current limiting function (see 4.3.6) shall be tested at the multiple of current settings of Table 37 that are below the current limiting operating point. The load shall then be adjusted to the point at which the current limiting function operates. The *BDM/CDM* shall *trip* within the time established by the curve in Figure 25 for the current at which the current limit function operates. If the current limiting operating point is below 1,2 times the current, the *BDM/CDM* shall ultimately *trip* when tested at the current limiting operating point. Multiple of current settings of Table 37 that are above the current limiting operating point do not require verification.

For example, a *BDM/CDM* that has a current limiting function that operates at a multiple of current setting of 4,0 shall be tested at 1,2, 1,5 and 4,0 multiples of current. The multiple of current setting of 7,2 is not required to be tested.

BDM/CDM that are suitable for controlling a range of motors shall be adjusted for the smallest motor rating of which the *BDM/CDM* installation instructions specifies that motor overload protection has been provided.

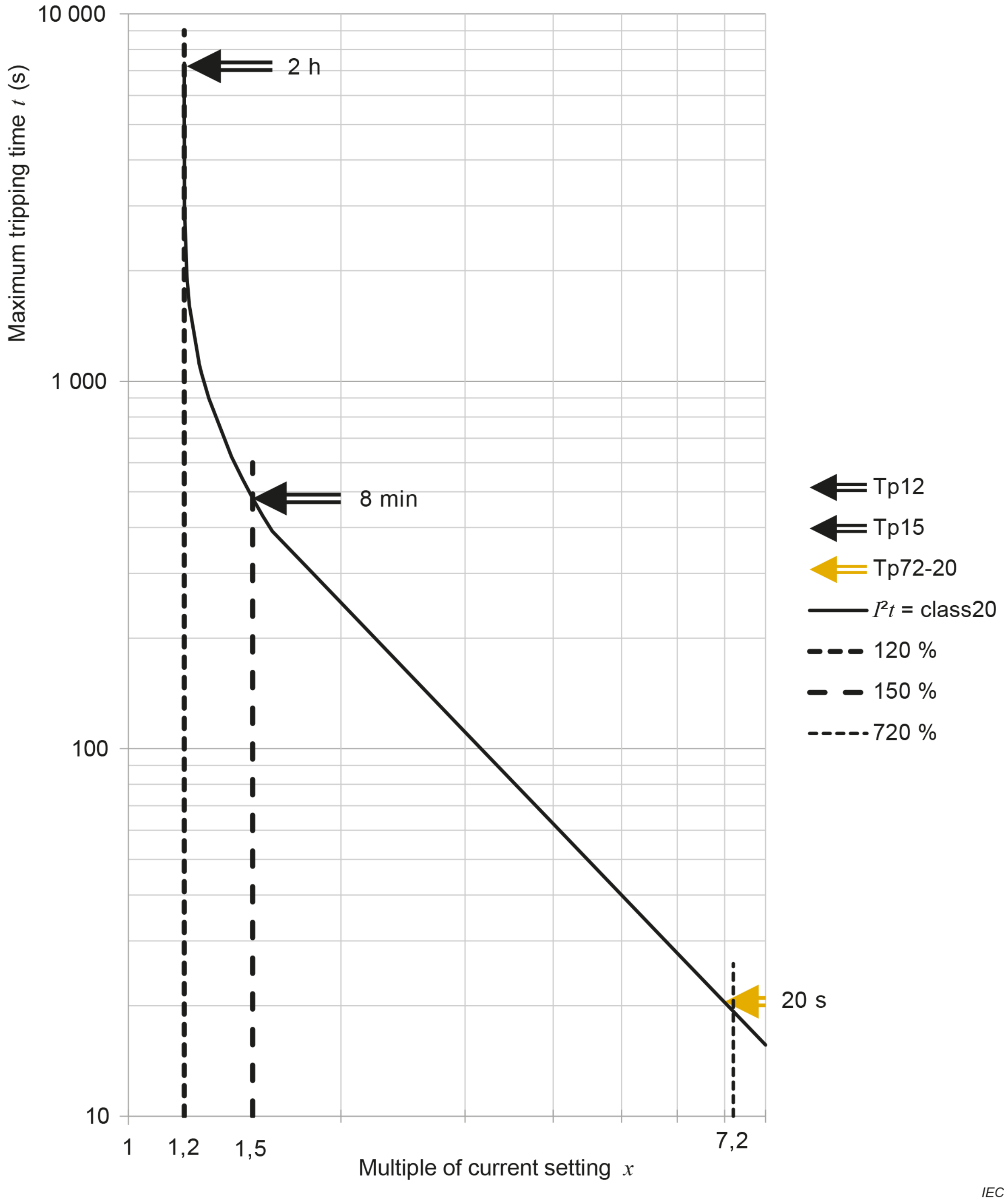


Figure 25 – Interpolated values for Table 37

In Figure 25, the relationship of the tripping time t versus multiple of current setting x limits

- with x less than or equal to 1,6 is given by $t = -470 \times \ln(1 - 1{,}2^2/x^2)$ from a first order approximation response with a time constant of 470 s and tripping at $1{,}2^2$, and
- with x above 1,6 is given by a constant $x^2 t = 1\,000$ from an adiabatic approximation response.

5.2.4.6.5 Electronic motor *thermal memory retention trip* test (*type test*)

The purpose of this test is to verify that the *electronic motor overload protection* functionality evaluated under 5.2.4.6.4 maintains the *thermal memory* when the *BDM/CDM* is restarted after a *trip*. The test shall be conducted under the conditions specified in 5.2.4.6.5.

The test is conducted as follows:

a) the *thermal memory* of the *BDM/CDM* is reset;
b) the *BDM/CDM* shall be operated at any multiple of current setting according to Table 37 until the overload protection trips the *BDM/CDM*; the duration between the start of the overload condition and tripping is the first elapsed time;
c) without removing the power supply, the test shall be immediately restarted with the same overload condition, within a time shorter than the first elapsed time;
d) the *BDM/CDM* shall be operated until the overload protection trips the *BDM/CDM* again;
e) the duration between the start of the second overload condition and tripping is the second elapsed time.

Compliance is shown when the second elapsed time until tripping is less than the first elapsed time.

For information requirements, see 6.3.9.7.

5.2.4.6.6 Electronic motor *thermal memory retention* loss of power test (*type test*)

The purpose of this test is to verify that the *electronic motor overload protection* evaluated under 5.2.4.6.4 maintains the *thermal memory* when the *BDM/CDM* is restarted after a *trip* and loss of the supply voltage. The test shall be conducted under the conditions specified in 5.2.4.6.6.

The test is conducted as follows:

a) the *thermal memory* of the *BDM/CDM* is reset;
b) the *BDM/CDM* shall be operated at any multiple of current setting according to Table 37 until the overload protection trips the *BDM/CDM*;
c) the duration between the start of the overload condition and tripping is the first elapsed time;
d) all power supplies shall be removed from the *BDM/CDM*;
e) wait until all circuits for control functions cease to operate, except for circuits that are powered by an internal source, such as a battery;
f) immediately following, power supplies shall be restored to the *BDM/CDM*;
g) the test shall be immediately restarted with the same overload condition within a time shorter than the first elapsed time;
h) the *BDM/CDM* shall be operated until the overload protection trips the BDM/CDM again;
i) the duration between the start of the second overload condition and tripping is the second elapsed time.

Compliance is shown when the second elapsed time until tripping is less than the first elapsed time.

Step e) may be omitted if the manufacturer demonstrates that the stored *thermal memory* data is retained for a duration long enough to ensure protection of the motor.

For information requirements, see 6.3.9.7.2.

5.2.4.6.7 Electronic motor thermal speed sensitivity test (*type test*)

The purpose of this test is to verify that the *electronic motor overload protection* functionality evaluated under 5.2.4.6.4 maintains the *thermal memory* under reduced motor speed. The test shall be conducted under the conditions specified in 5.2.4.6.7.

NOTE Motors with a fan impeller mounted on the shaft have reduced cooling at low speed.

The test is conducted as follows:

a) the *thermal memory* of the *BDM/CDM* is reset;
b) the *BDM/CDM* shall be operated at 40 % of the rated output frequency (for AC output) or voltage (for DC output), while delivering any multiple of current setting according to Table 37 until the overload protection trips the *BDM/CDM*;
c) the duration between the start of the overload condition and tripping is the first elapsed time;
d) the thermal memory of the *BDM/CDM* is reset;
e) the *BDM/CDM* shall be immediately restarted at 20 % of the rated output frequency (for AC output) or voltage (for DC output), with the same overload condition;
f) the *BDM/CDM* shall be operated until the overload protection trips the *BDM/CDM* again;
g) the duration between the start of the second overload condition and tripping is the second elapsed time.

Compliance is shown when the second elapsed time until tripping is less than the first elapsed time.

If testing *BDM/CDM* with the values above is not possible due to the motor characteristic, more practical values for the frequency or voltage may be selected.

For *PDS* where motor and *BDM/CDM* are known, limits of above test settings may be selected depending on the motor characteristic.

For information requirements, see 6.3.9.7.2.

5.2.4.7 Circuit functionality evaluation test (*type test*, *routine test, sample test*)

Circuit functionality evaluation is required for the verification of hardware and software when used for compliance with *type tests* as required by

a) *electronic power output short-circuit protection* according to 5.2.4.5, and
b) *electronic motor overload protection* according to 5.2.4.6.

NOTE The verification of the functionality does not require to perform all steps of 5.2.4.5 and 5.2.4.6, but only to verify that the protection is available.

Prior to being shipped from the manufacturing facility, all *electronic power output short-circuit protections* and *electronic motor overload protections* shall be subjected to a procedure involving

c) identification of early production faults as a *sample test* or *routine test*, and
d) verification of functionality as a *routine test*.

This identification and verification procedure may include one of the following:

e) an incoming *component* screening;
f) a burn-in method that varies in conditions (such as duration, temperature, and similar conditions);
g) a diagnostic test, which may be accomplished by providing signals for the software and/or hardware.

5.2.4.8 Current limiting test (*type test*)

BDM/CDM/PDS incorporating a current limiting control according to 4.3.6 shall be operated with the load increased such that the current limit mode is reached. When the current limiting control is adjustable, it shall be adjusted to result in the most severe condition.

5.2.4.9 Output overload test (*type test*)

When required by 4.6.1, the output overload test shall be performed after operating the *BDM/CDM/PDS* at full load until normal operating temperatures are attained. Except for outputs that comply with the limited power source requirements of 4.5.3, each output power *port* of the *BDM/CDM/PDS* and each section of a tapped output shall be overloaded in turn, one at a time. The other output power *ports* are loaded or not loaded, whichever load condition under normal operating condition is less favourable.

The output overload test current shall be obtained by connecting a variable load across the output power *port*. The load is adjusted as quickly as possible and readjusted, if necessary, after 1 min to maintain the applicable overload. No further readjustments are then permitted.

The output overload test current shall comply with one of the following:

a) for *BDM/CDM/PDS* where *overcurrent* protection is provided by a current-sensitive device or circuit, the overload test current is the maximum current which the *overcurrent protective device* is just capable of passing for 1 h. Before the test, the *overcurrent protective device* is made inoperative or replaced by a link with negligible impedance;
b) for *BDM/CDM/PDS* in which the output voltage is designed to collapse when a specified overload current is reached, the overload is slowly increased to the point of maximum output power before the point which causes the output voltage to collapse.

In all other cases, the loading is the maximum power output obtainable from the output power *port*.

5.2.4.10 Breakdown of *component* test (*type test*)

5.2.4.10.1 Load conditions

The breakdown of a *component*, identified as a result of the circuit analysis of 4.2, shall be tested with the *BDM/CDM/PDS* at full load or light load, whichever creates the more severe condition.

5.2.4.10.2 Application of short-circuit or open-circuit

The short-circuit shall be applied with cable of a cross-section appropriate for the current that will flow through the *component* during the fault for the duration of the test without fusing, but not less than 2,5 mm^2. The length of the loop shall be as short as practical to perform the test. Short-circuits and open-circuits are applied using an appropriate switching device capable of carring the fault current for the duration of the test.

Each identified *component* shall be subjected to

- only one breakdown of *component* test unless both open- and short-circuit failure modes are likely in that *component*, and
- the relevant breakdown of *component* tests as shown in the evaluation in 4.2.

5.2.4.10.3 Test sequence

For the breakdown of *component* test, identified *components* shall be short-circuited or open-circuited, whichever creates the worst hazard, one at a time. If the analysis from 4.2 does not define which condition creates the worst case, then both the short-circuit and open-circuit test are required.

See 5.2.4.3 for acceptance criteria.

5.2.4.11 PWB short-circuit test (*type test*)

On PWBs and components assembled on PWB, *functional insulation* may be provided by *clearance* and *creepage distances* which are less than those specified in 4.4.7.4 and 4.4.7.5. The decreased *clearance* and *creepage distances* shall be short-circuited one at a time, on representative samples, and the short-circuit shall be maintained until no further damage occurs.

See 5.2.4.3 for acceptance criteria.

5.2.4.12 Loss of phase test (*type test*)

A multi-phase *BDM/CDM/PDS* shall be operated with each phase (including neutral, if used) disconnected in turn at the input. The test shall be performed by disconnecting one phase with the *BDM/CDM/PDS* operating at its maximum normal load and shall be repeated by initially energizing the *BDM/CDM/PDS* with one lead disconnected.

If the disconnection of a single phase can decisively be determined to result in a more severe condition, for example disconnection of the phase with the protective device least likely to respond to the loss of phase, then the test can be conducted by disconnecting only that phase instead of each phase in turn.

The test shall continue until terminated by a protective mechanism, a *component* failure occurs, or the temperature stabilizes.

For *BDM/CDM/PDS* with rated input current greater than 500 A, compliance can be shown through simulation.

NOTE If fuses are used, a voltage can remain at the open phase caused by internal impedances within the *BDM/CDM/PDS* connected between the phases.

5.2.4.13 Cooling failure test (*type test*)

5.2.4.13.1 General and acceptance criteria

For *BDM/CDM/PDS* having a combination of cooling mechanisms, all relevant tests shall be performed. It is not necessary to perform the tests simultaneously.

The test shall continue until

- the temperature stabilizes, in which case the temperature limits for *accessible part*s of 4.6.5.3 apply, or
- terminated by a protective mechanism or a *component* failure occurs, in which case the temperature limits of *accessible part*s in 4.6.5.3 may be exceeded by not more than 5 °C.

When this limitation of the temperature is not possible, a warning statement shall be provided according to 6.4.4.

NOTE The temperature increase of 5 °C, with regard to the steady state limits, reflects the spread of the burn threshold given in IEC Guide 117.

5.2.4.13.2 Inoperative blower motor test (*type test*)

A *BDM/CDM/PDS* having forced ventilation shall be operated at rated load with fan or blower motor or motors made inoperative by physically preventing their rotation. If more than one blower motor is comprised, analysis of 4.2 shall demonstrate whether one after the other or more at the same time shall be blocked, taking into account a *single-fault condition*.

NOTE In order to avoid hazards during this test, the physical prevention of the rotation can be done before energizing the blower motor.

5.2.4.13.3 Clogged filter test (*type test*)

Enclosed *BDM/CDM/PDS* having filtered ventilation openings shall be operated at rated load with the openings blocked to represent clogged filters.

The test shall be performed initially with 50 % of the ventilation openings surface blocked. The test shall be repeated under a full blocked condition.

5.2.4.13.4 Loss of coolant test (*type test*)

A liquid cooled *BDM/CDM/PDS* shall be operated at rated load. Loss of coolant shall be simulated by draining the coolant, blocking the flow or disabling the *system* coolant pump.

If the *BDM/CDM/PDS* is shut down due to the operation of a thermal device located inside the coolant, then the test shall be repeated with the coolant drained out of the *system*.

NOTE It is presumed that the thermal device will be inoperative if not surrounded by coolant liquid.

5.2.4.13.5 Covering of openings for cooling air test (*type test*)

All openings of a *movable BDM/CDM/PDS* are covered simultaneously.

Openings above 1,8 m do not need to be blocked.

5.2.5 Material tests

5.2.5.1 General

When required by 4.4.7.8.2, the flammability properties of the materials used for insulating purposes shall be tested, as defined in 5.2.5.2, 5.2.5.3 and 5.2.5.4.

When required by 4.6.4.2, the flammability properties of the materials used for *fire enclosure* shall be tested, as defined in 5.2.5.5.

NOTE In the USA, materials tests are not required.

5.2.5.2 High current arcing ignition test (*type test*)

Five test samples of each insulating material (see Figure 26) to be tested are used. The samples shall have minimum 130 mm length and 13 mm width and be of uniform thickness representing the thinnest section of the part. Edges shall be free from burrs, fins, etc.

Each test is made with a pair of test electrodes and a variable inductive impedance load connected in series to a source of 220 V to 240 V AC, 50 Hz or 60 Hz (see Figure 26).

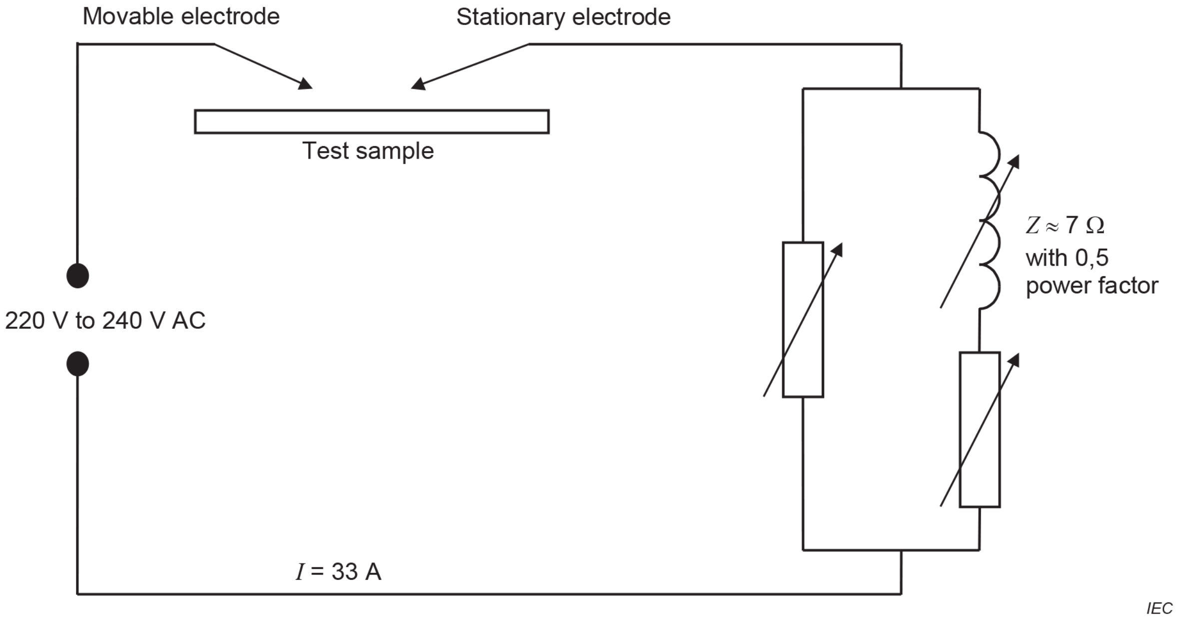


Figure 26 – Circuit for high-current arcing test

It is permitted to use an equivalent circuit.

One electrode is stationary and the second movable. The stationary electrode consists of a 3,5 mm diameter solid copper conductor having a 30° chisel point. The movable electrode is a 3 mm diameter stainless steel rod with a symmetrical conical point having a total angle of 60° and is capable of being moved along its own axis. The radius of curvature for the electrode tips does not exceed 0,1 mm at the start of a given test. The electrodes are located opposing each other, in the same plane, at an angle of 45° to the horizontal. With the electrodes short-circuited, the variable inductive impedance load is adjusted until the current is 33 A at a power factor of 0,5.

The sample under test is supported horizontally in air or on a non-conductive surface so that the electrodes, when touching each other, are in contact with the surface of the sample. The movable electrode is manually or otherwise controlled so that it can be withdrawn from contact with the stationary electrode to break the circuit and lowered to remake the circuit, so as to produce a series of arcs at a rate of approximately 40 arcs/min, with a separation speed of 250 mm/s ± 25 mm/s.

The test is continued until ignition of the sample occurs, a hole is burned through the sample or a total of 200 arcs have elapsed.

The average number of arcs to ignition of the specimens tested shall be according to Table 11.

5.2.5.3 Glow-wire test (*type test*)

The glow-wire test shall be made under the conditions specified in 4.4.7.8.2 according to IEC 60695-2-10:2021 and IEC 60695-2-13:2021.

If the test shall be made at more than one place on the same sample, care should be taken to ensure that any deformation caused by previous tests does not affect the test to be made.

NOTE Depending on the classification of the use of the *BDM/CDM*, the glow-wire test is performed at a lower test temperature according to IEC 60695-2-11:2021, Figure A.1, but not less than 550 °C or the applicable temperature of 850 °C. The test temperature is derived from IEC 60695-2-11:2021, Annex A, for equipment for unattended use continuously loaded.

5.2.5.4 Hot wire ignition test (*type test* – alternative to glow-wire test)

The hot wire ignition test is an alternative to the glow-wire test.

Five samples of each insulating material (see Figure 27) are tested. The samples shall have minimum 130 mm length and 13 mm width and of a uniform thickness representing the thinnest section of the part. Edges shall be free from burrs, fins, etc.

A 250 mm ± 5 mm length of nichrome wire (nominal composition 80 % nickel, 20 % chromium, iron-free) approximately 0,5 mm diameter and having a cold resistance of approximately 5 Ω/m is used. The wire is connected in a straight length to a variable source of power which is adjusted to generate 0,25 W/mm ± 0,01 W/mm in the wire for a period of 8 s to 12 s. After cooling, the wire is wrapped around a sample to form five complete turns spaced 6 mm apart.

The wrapped sample is supported in a horizontal position (see Figure 27) and the ends of the wire connected to the variable power source, which is again adjusted to generate 0,25 W/mm ± 0,01 W/mm in the wire.

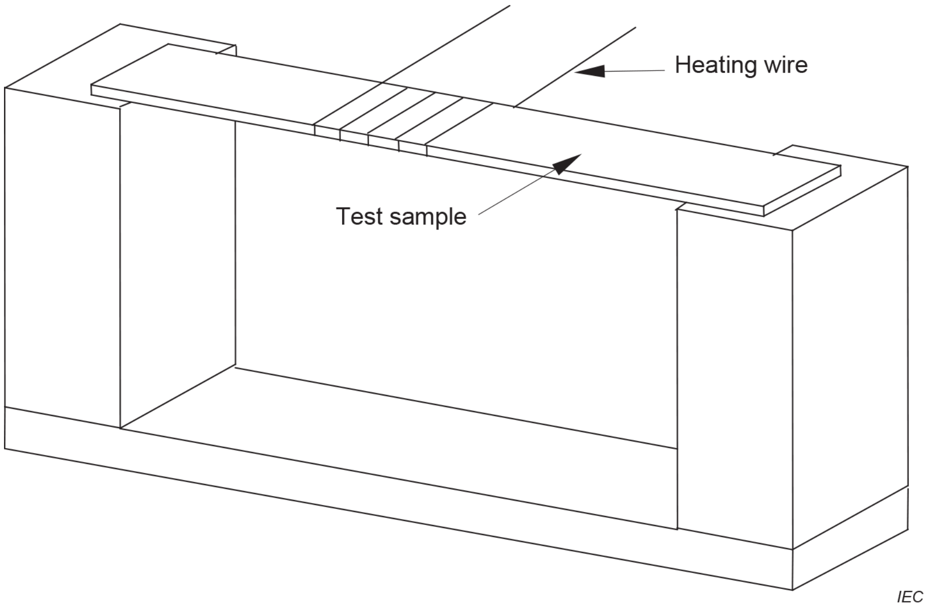


Figure 27 – Test fixture for hot-wire ignition test

The test is continued until the test specimen ignites or until 120 s have passed. When ignition occurs or 120 s have passed, the test is discontinued and the test time recorded. For specimens which melt through the wire without ignition, the test is discontinued when the specimen is no longer in intimate contact with all five turns of the heater wire.

The test is repeated on the remaining samples.

The average ignition time of the specimens tested shall be according to Table 11.

5.2.5.5 Flammability test (*type test*)

Three samples of the complete *BDM/CDM* or three test specimens of the *enclosure* thereof (see 4.6.4.2) shall be subjected to this test. Consideration shall be given to leaving in place *components* and other parts that might influence the performance. The test samples shall be conditioned in a full draft circulating air oven for seven days at 10 °C greater than the maximum use temperature, as determined by the temperature rise test in 5.2.3.10, but not less than 70 °C in any case. Prior to testing, the samples shall be conditioned for a minimum of 4 h at 23 °C ± 2 °C and 50 % ± 5 % relative humidity. The flame shall be applied to an inside surface of the sample at a location judged to be likely to become ignited because of its proximity to a source of ignition including surfaces provided with ventilation holes. If more than one part is near a source of ignition, each sample shall be tested with the flame applied to a different location.

The three test samples shall result in the acceptable performance described below. If one sample does not comply, the test shall be repeated on a set of three new samples with the flame applied under the same conditions as for the unsuccessful sample. If all the new specimens comply with the requirements described below, the material is acceptable.

The laboratory burner, adjustment and calibration shall be identical to that described in IEC 60695-11-20:2015.

When a complete *enclosure* is used to conduct the flame test, the sample shall be mounted as intended in service, if it does not impair the flame testing, in a draft-free test chamber, *enclosure*, or laboratory hood. A layer of absorbent 100 % cotton shall be located 305 mm below the point of application of the test flame. The 127 mm flame shall be applied to any portion of the interior of the part judged as likely to be ignited (by its proximity to live or arcing parts, coils, wiring, and the like) at an angle of approximately 20 ° insofar as possible from the vertical so that the tip of the blue cone touches the specimen. The test flame shall be applied to three different locations on each of the three samples tested. A supply of technical-grade methane gas shall be used with a regulator and meter for uniform gas flow. Natural gas having a heat content of approximately 37 MJ/m^3 at 23 °C has been found to provide similar results and may be used.

The flame shall be applied for 5 s and removed for 5 s. The operation shall be repeated until the specimen has been subjected to five applications of the test flame.

The following conditions shall be met as a result of this test:

- the material shall not continue to burn for more than 1 min after the fifth 5 s application of the test flame, with an interval of 5 s between applications of the flame;
- flaming drops or flaming or glowing particles that ignite surgical cotton 305 mm below the test specimen shall not be emitted by the test sample at any time during the test.

After the test, *BDM/CDM* shall meet the requirements for *basic protection* by means of *enclosures* or barriers in 4.4.3.3.

5.2.5.6 Cemented joints test (*type test*)

When required by 4.4.7.9, representative samples of cemented joints providing protection of type 1 or type 2 as defined in IEC 60664-3:2016 shall be tested as a *type test* as follows. For the quantity of samples to be tested, see IEC 60664-3:2016.

The samples shall be subjected to the preconditioning according to 5.2.3.16.

After the preconditioning, the samples shall pass the following tests in the prescribed order.

a) The mechanical strength of the joint shall be evaluated by loading the joint using the forces anticipated to be present under normal conditions. There shall be no separation of the parts.

b) The insulation resistance between the conductive parts separated by the joint shall be measured according to IEC 60664-3:2016, 5.8.3. The minimum value for the insulation resistance between the conductors shall be 100 MΩ.

c) The complete mechanical assembly or equivalent sample shall be tested as solid insulation according to 4.4.7.8.

d) The sectioning of the joint shall not show any cracks, voids or separation when verified by visual inspection in 5.2.1 according to IEC 61189-3:2007, 6.2 (test 3V02).

5.2.5.7 Ultra-violet (UV) resistance test (*type test*)

If required in 4.12.9 for polymeric outdoor *enclosure*, *type test*s shall be performed to demonstrate sufficient resistance to UV exposure.

Samples taken from the parts, or consisting of identical material, are prepared according to the standard for the test to be carried out (see IEC 62109-1:2010, Table 27). They are then UV conditioned according to IEC 62109-1:2010, Annex J.

After conditioning, the samples shall show no signs of significant deterioration, such as crazing or cracking. They are then kept at room ambient conditions for not less than 16 h and not more than 96 h, after which they are tested according to the standard for the relevant test.

In order to evaluate the percent retention of properties after test, samples that have not been conditioned according to IEC 62109-1:2010, Annex J, are tested at the same time as the conditioned samples.

Except for flammability classification (see 4.6), use IEC 62109-1:2010, Table 27, for the minimum property retention limits after test.

5.2.6 Environmental tests (*type test*s)

5.2.6.1 General

Environmental testing is required to establish the safety of the *BDM/CDM/PDS* at the extremes of the environmental classification to which it will be subjected according to 4.9.

NOTE In the USA and Canada, environmental tests are not required.

If size or power considerations prevent the performance of these tests on the complete *BDM/CDM/PDS*, it is permitted to test individual parts that are considered to be relevant to the safety of the *BDM/CDM/PDS*.

When testing *components* or sub-assemblies separately, the temperature during the dry-heat test shall be chosen as to simulate actual use in the end-product. The *component* or sub-assembly shall be energized simulating the same conditions as in the end-product.

Table 38 shows the tests to be performed for the different environmental conditions.

Compliance is shown by conducting test of 5.2.6.3, 5.2.6.4, 5.2.6.5, 5.2.6.6 and 5.2.6.7 according to Table 38 as applicable for the environmental conditions specified by the manufacturer.

Where the *BDM/CDM/PDS* is specified to operate in conditions outside the range of values given in this document, then the test conditions shall be according to the range of values stated in the user documentation. In any case, the test requirements shall not be less demanding than the operating conditions specified.

Table 38 – Environmental tests

Test condition	Indoor unconditioned	Outdoor unconditioned
Standard	IEC 60721-3-3:1994, 60721-3-3/AMD1:1995 and 60721-3-3/AMD2:1996 [b]	IEC 60721-3-4:2019
Climatic	Preconditioning or recovery procedure for climatic tests (see 5.2.6.3.1)	Preconditioning or recovery procedure for climatic tests (see 5.2.6.3.1)
	Dry heat (see 5.2.6.3.2) Test Bd of IEC 60068-2-2:2007	Dry heat (see 5.2.6.3.2) Test Bd of IEC 60068-2-2:2007
	Cold test (see 5.2.6.3.3) Test Ad of IEC 60068-2-1:2007	Cold test (see 5.2.6.3.3) Test Ad of IEC 60068-2-1:2007
	Damp heat (steady state) (see 5.2.6.3.4) Test Cab of IEC 60068-2-78:2012	Damp heat (steady state) (see 5.2.6.3.4) Test Cab of IEC 60068-2-78:2012
	No test requirement	Damp heat (cyclic) (see 5.2.6.3.5) Test Db of IEC 60068-2-30:2005
Chemically active substances	No test requirement	Test Kb of IEC 60068-2-52:2017 Salt mist [a] (see 5.2.6.5)
Mechanically active substances	No test requirement	Test Lc of IEC 60068-2-68:1994 Dust and sand (see 5.2.6.6 and 5.2.6.7)
Mechanical	Test Fc of IEC 60068-2-6:2007 Vibration (see 5.2.6.4)	Test Fc of IEC 60068-2-6:2007 Vibration (see 5.2.6.4)
Biological	No test requirement	No test requirement
UV resistance	No test requirement	5.2.5.7

[a] Refer to footnote [a] in Table 20.

[b] In this document, no cold test is required for indoor use.

When special environmental conditions are specified, additional tests (e.g. for chemically active substances) shall be considered.

5.2.6.2 Acceptance criteria

The following acceptance criteria shall be satisfied:

a) no degradation of any safety-relevant *component* of the *BDM/CDM/PDS*;
b) no potentially hazardous behaviour of the *BDM/CDM/PDS* during the test;
c) no sign of *component* overheating;
d) no *hazardous live part* shall become accessible;
e) no cracks in the *enclosure* and no damaged or loose insulators;
f) pass routine AC or DC voltage test 5.2.3.4;
g) pass *protective equipotential bonding* continuity test 5.2.3.11.2;
h) no potentially hazardous behaviour when the *BDM/CDM/PDS* is operated following the test.

5.2.6.3 Climatic tests

5.2.6.3.1 Preconditioning or recovery procedure for climatic tests (*type test*)

The preconditioning or recovery procedure for climatic tests shall be performed as described in Table 39.

Table 39 – Preconditioning or recovery procedure for climatic tests (*type test*)

Precondition or recovery procedure	
– Time	1 h minimum
– Climatic conditions	
• Temperature	15 °C to 35 °C uncontrolled or as required in the individual test
• Relative humidity	25 % to 75 %, uncontrolled
• Barometric pressure	86 kPa to 106 kPa
– Power supply	Power supply unconnected
– Condensation for recovery procedure only	All external and internal condensation shall be removed by air flow prior to performing the AC or DC voltage test or re-connecting the *BDM/CDM/PDS* to a power supply.
NOTE The values of this table comply with Table 24.	

5.2.6.3.2 Dry heat test (steady state) (*type test*)

To prove the ability of *components* and *BDM/CDM/PDS* to be operated, transported or stored at high temperatures, the dry heat (steady state) test shall be performed according to the conditions specified in Table 40.

Table 40 – Dry heat test (steady state) (*type test*)

Subject	**Test conditions**
Initial selection and *visual inspection* before test	According to 5.1.2 and 5.2.1
Preconditioning procedure	According to Table 39
Test	
Test reference	IEC 60068-2-2:2007, Test Bd
Requirement reference	4.9
Operating conditions	Operating at rated conditions
– Temperature	Temperature classification according to high temperature in Table 20 or manufacturer's specified highest temperature, whichever is more severe.
– Accuracy	±2 °C (see IEC 60068-2-2:2008)
– Humidity	25 % to 75 % uncontrolled
– Duration of exposure	≥ 16 h
Recovery procedure	According to Table 39.

5.2.6.3.3 Cold test (*type test*)

To prove the ability of *components* and *BDM/CDM/PDS* to be operated, transported or stored at low temperatures, the cold test shall be performed according to the conditions specified in Table 41.

Table 41 – Cold test (*type test*)

Subject	Test conditions
Initial selection and *visual inspection* before test	According to 5.1.2 and 5.2.1
Preconditioning procedure	According to Table 39
Test	
Requirement reference	4.9
Test reference	IEC 60068-2-1, Test Ad
Operating conditions	After preconditioning and thermal stabilisation is achieved, starting of operation according to manufacturers specification. Operation shall be demonstrated by *visual inspection* in 5.2.1, measurement or by applying a load.
Special precautions	Thermal losses from operating the test sample shall not influence the test result.
Temperature	Temperature classification according to low temperature in Table 20 or manufacturer's specified lowest temperature, whichever is more severe.
Accuracy	±3 °C (see IEC 60068-2-1)
Humidity	Not controlled
Duration of exposure	≥ 16 h
Recovery procedure	According to Table 39.

5.2.6.3.4 Damp heat test (steady state) (*type test*)

To prove the resistance to humidity, the *BDM/CDM/PDS* shall be subjected to a damp heat test (steady state) according to the conditions specified in Table 42.

Table 42 – Damp heat test (steady state) (*type test*)

Subject	Test conditions
Initial selection and *visual inspection* before test	According to 5.1.2 and 5.2.1
Preconditioning procedure	According to Table 39
Test	
Test reference	IEC 60068-2-78:2012, test Cab
Requirement reference	4.9
Operating conditions	Power supply disconnected
Special precautions	Internal voltage sources may remain connected if the heat produced by them in the specimen is negligible.
Temperature	40 °C
Accuracy	±2 °C (see IEC 60068-2-78:2012, Clause 5)
Humidity	93 % R.H. controlled or manufacturer's specified highest humidity, whichever is more severe.
Accuracy	±3 % (see IEC 60068-2-78:2012, Clause 5)
Duration of exposure	≥ 96 h
Recovery procedure	According to Table 39.

5.2.6.3.5 Damp heat test (cyclic) (*type test*)

To prove the resistance of *components* and *BDM/CDM/PDS* to condensation, a damp heat test (cyclic) according to the conditions specified in Table 43 shall be performed if condensation is expected.

Table 43 – Damp heat test (cyclic) (*type test*)

Subject	Test conditions
Initial selection and *visual inspection* before test	According to 5.1.2 and 5.2.1
Preconditioning procedure	According to Table 39
Test	
Test reference	IEC 60068-2-30:2005, test Db, variant 2
Requirement reference	4.9
Operating conditions	After preconditioning and thermal stabilisation is achieved, starting of operation according to manufacturer's specification. Operation shall be demonstrated by *visual inspection* in 5.2.1, measurement or by applying a load.
Special precautions	Thermal losses from operating the test sample shall not influence the test result.
Humidity	See IEC 60068-2-30:2005, Figure 2b
Accuracy	±3 % RH (see IEC 60068-2-30:2005)
Duration of exposure	See IEC 60068-2-30:2005, Figure 2b
Lower temperature	25 °C
Upper temperature	40 °C
Accuracy	±3 °C (see IEC 60068-2-30:2005)
Number of cycles	2 (48 h)
Rise and fall time of the temperature	See IEC 60068-2-30:2005, Figure 2b
Recovery procedure	According to Table 39

5.2.6.4 Vibration test (*type test*)

To verify the mechanical vibration strength, the *BDM/CDM/PDS* in combination with its *installation* shall be evaluated by

a) tests defined in 5.2.6.4 according to the conditions specified in Table 44, or

b) calculation or simulation based on tests, as defined in 5.2.6.4, on a representative model of *BDM/CDM/PDS*.

For *BDM/CDM/PDS* with a mass more than 100 kg, this test may be performed on sub-assemblies.

NOTE For large *BDM/CDM/PDS*, the possibility of using a shock test as an alternative to a vibration test is under consideration.

Table 44 – Vibration test

Subject	Test conditions
Test reference	Test Fc of IEC 60068-2-6:2007
Requirement reference	4.9
Initial selection and *visual inspection* before test	According to 5.1.2 and 5.2.1
Conditions	Power supply unconnected
Motion	Sinusoidal
Vibration amplitude/acceleration	
10 Hz ≤ f ≤ 58 Hz	0,075 mm amplitude
58 Hz ≤ f ≤ 150 Hz	10 m/s^2 (1 g)
Vibration duration	10 sweep cycles per axis on each of three mutually perpendicular axes
Detail of mounting	According to manufacturer's specification
Number of test samples	1 sample for all axes
Where the manufacturer specifies vibration levels that are greater than those above, the higher levels shall be used for the test. The acceptance criteria shall not be changed. NOTE This test is an accelerated test which means that the level is higher than indicated in Table 20.	

5.2.6.5 Salt mist test (*type test*)

To verify the resistance against salt mist, the *BDM/CDM/PDS* in combination with its *installation* shall be evaluated by tests defined in 5.2.6.5 according to the conditions specified in Table 45.

Table 45 – Salt mist test

Subject	Test conditions
Test reference	Test Kb of IEC 60068-2-52:2017
Requirement reference	Table 38
Initial selection and *visual inspection* before test	According to 5.1.2 and 5.2.1
Conditions	Power supply unconnected
Severity level	Test method 2
Acceptance criteria	5.2.6.2
Where the *BDM/CDM/PDS manufacturer* specifies salt mist levels that are greater than those above, the higher levels shall be used for the test. The acceptance criteria shall not be changed. Where the environmental conditions are known to be lower, the *BDM/CDM/PDS manufacturer* might specify lower level or no salt mist test than those specified in this table. The acceptance criteria shall not be changed.	

5.2.6.6 Dust test (*type test*)

To verify the ability to operate under the influence of dust, the *BDM/CDM/PDS* in combination with its *installation* shall be evaluated by tests defined in 5.2.6.6 under the conditions specified in Table 46 mainly to demonstrate the tightness against dust.

For *BDM/CDM/PDS* with a mass more than 100 kg, this test may be performed on sub-assemblies.

Table 46 – Dust test

Subject	Test conditions
Test reference	According to chosen IP class of IEC 60529
Requirement reference	Table 38
Initial selection and *visual inspection* before test	According to 5.1.2 and 5.2.1
Conditions	Power supply unconnected
Particle size	According to IEC 60529
Dust concentration	According to IEC 60529
Air velocity	According to IEC 60529
Air pressure in the specimen	According to IEC 60529
Test duration	According to IEC 60529
Acceptance criteria	5.2.6.2 and according to chosen IP classification from IEC 60529

5.2.6.7 Sand test (*type test*)

To verify the ability to operate under the influence of sand, the *BDM/CDM/PDS* in combination with its *installation* shall be evaluated by tests defined in 5.2.6.7 under the conditions specified in Table 47 mainly to demonstrate the robustness against abrasion by sand.

Table 47 – Sand test

Subject	Test conditions
Test reference	Test Lc1 of IEC 60068-2-68:1994
Requirement reference	Table 38
Initial selection and *visual inspection* before test	According to 5.1.2 and 5.2.1
Conditions	Power supply unconnected
Particle size	Fine dust
Dust concentration	2 g/m^3
Air velocity	5 m/s
Air pressure in the specimen	Air pressure in the specimen is that of the ambient air pressure.
Test duration	24 h
Acceptance criteria	5.2.6.2

5.2.7 Hydrostatic pressure test (*type test, routine test*)

For *type tests*, the pressure inside the cooling *system* of a liquid cooled *BDM/CDM/PDS* (see 4.7.4.3.3) shall be increased at a gradual rate until a pressure relief mechanism (if provided) operates, or until a pressure of twice the operating value or 1,5 times the maximum pressure rating of the *system* is achieved, whichever is the greater.

For the purpose of this test, the coolant pump may be disabled.

For *routine tests*, the pressure shall be increased to the maximum pressure rating of the *system*.

For both, *type test* and *routine test* a suitable liquid shall be used to detect leakage.

NOTE 2 Pretesting prior *routine test* with compressed air can be performed.

The pressure shall be maintained for at least one minute.

Acceptance criteria:

- there shall be no thermal, electric shock, or other hazard resulting from the test;
- there shall be no leakage of coolant or loss of pressure during the test, other than from a pressure relief mechanism during a *type test*;
- the *BDM/CDM/PDS* shall pass the AC or DC voltage test in 5.2.3.4 after the hydrostatic pressure *type test*.

5.2.8 Electromagnetic fields (EMF) test (*type test*)

See Clause P.4.

6 Information and marking requirements

6.1 General

6.1.1 Overview

The purpose of Clause 6 is to define the information necessary for the safe selection, installation and commissioning, operation and maintenance for the intended use of *BDM/CDM/PDS*.

It is presented as Table 48, showing where the information shall be provided, followed by explanatory subclauses. In case of conflicts, the requirements in the text of the clauses is mandatory.

The requirements of Clause 6 applies to all *BDM/CDM/PDS*, unless otherwise stated.

Since any electrical equipment can be installed or operated in such a manner that hazardous conditions can occur, compliance with the design requirements of this document does not by itself assure a safe installation. However, when equipment complying with those requirements is properly selected and correctly installed and operated, the hazards will be minimized.

The manual shall inform that, for the purpose of installation, operation and maintenance, a manual shall be available at the end user location where the *BDM/CDM/PDS* is installed.

The manual shall also indicate any hazards which can result from reasonably foreseeable misuse of the *PDS*.

All information shall be in an appropriate language and documents shall have identification references. Drawing symbols shall conform to IEC 60417 or IEC 60617 as appropriate. Symbols not shown in IEC 60417 or IEC 60617 shall be identified where used.

Compliance with the information and marking requirements in 6.1 to 6.5 is shown by *visual inspection* in 5.2.1.

The SI system shall be used when specifying electrical, mechanical and thermal units.

NOTE 1 In the USA, US customary inch-foot-pound units are widely used.

NOTE 2 In the USA and Canada, international symbols are not used in lieu of text.

NOTE 3 In Canada, there are two official languages, English and French. Subclause T.6.1.200 provides equivalent French translations of markings specified in this document.

NOTE 4 Further guidance for the preparation of documentation is provided in IEC 61082-1:2014, and for the preparation of instructions and manuals in IEC/IEEE 82079-1:2019.

Table 48 – Marking location

Information	Subclause reference	Location [a, b, c]					Technical subclause reference	In-some-country [h]
		1	**2**	**3**	**4**	**5**		
Identifying the product [d]	6.2.1.2	X	X		X	X	4.1	x
Electrical ratings for each *port* [d]	6.2.1.3 S.6.2.1.200.1 T.6.3.9.6.200	X	X			X	4.1	x
	S.6.2.1.200.2					X		USA
Supplementary information for each *port*	6.2.1.4 T.6.2.1.200					X	4.1	
Liquid cooled *BDM/CDM/PDS* [d, g]	6.2.1.5	X	X	X		X	4.1, 4.7.4	x
General *BDM/CDM/PDS* marking	6.2.1.6					X	4.1	x – multiple rated equip-ment only
		X						Canada
Instructions and markings pertaining to accessories [b, d, g, e]	6.2.2	X	X		X	X	4.1	x
Mechanical considerations	6.3.2					X	4.1	
IP rating for enclosed *BDM/CDM/PDS*	6.3.2, S.6.2.1	X				X	4.1, 4.12.1 T.4.12.1	x
Mass information [d]	6.3.2	X	X		X	X	4.1	
Environment	6.3.3 T.6.3.3					X	4.9, 4.4.7.1.3, 4.6.5	x – ambient tempera-ture rating only
Use in air handling compartments	S.6.3.3		X			X		USA
Handling and mounting	6.3.4					X	4.2	
Enclosure temperature	6.3.5 T.6.3.5.200					X	4.6.5.3	x
Open type *BDM/CDM* [d]	6.3.6					X	4.4.3.3.4, 4.6.4.3, 4.6.5	x
Connection, wiring, conductors, and terminals	6.3.7, S.6.3.7.2					X	4.1, 4.2, 4.11.1	x
Identification of *field wiring terminals*	6.3.7.4.1, S.6.3.7.4.1	X	X	X		X	4.4.6.5.3, 4.11.5, 4.11.11.3	x
Accessories for wire connection [f]	6.3.7.4.2 d)					X	--	x
Mains plug and socket-outlets	6.3.7.5	X	X	X		X	4.11.7	
Commissioning	6.3.8					X	4.1, 4.2	
Protection requirements	6.3.9	X				X	4.3, 4.4.3.3.2, 4.4.4.3, 4.4.6, 4.4.8, 4.11.5,	
Protective equipotential bonding circuit [g]	6.3.9.3	X	X			X	4.4.4.2, 4.4.4.3.2	
Touch current or high leakage current	6.3.9.4	X				X	4.4.4.3.3	X

Information	**Subclause reference**	**Location** [a, b, c]					**Technical subclause reference**	**In-some-country** [h]
		1	**2**	**3**	**4**	**5**		
Compatibility with RCD	6.3.9.5	X				X	4.4.8	
External protection means	6.3.9.6, S.6.3.9.6.1, S.6.3.9.6.2, S.6.3.9.6.3, S.6.3.9.6.4					X	4.1, 4.2, 4.3.2, 4.4.4.4, 4.4.7.2	x
Protection means for cord-connected *BCM/CDM/PDS*	S.6.3.9.6.5					X	S.4.11.10.1	USA
Motor overload protection and overtemperature protection [d, g]	6.3.9.7 T.6.3.9.7.201			X		X	4.3.5.2, 4.3.5.3, 4.3.5.4	X
	T.6.3.9.7.200		X					Canada
Combustible surface	T.6.3.5.200	X					4.6.5.3 T.4.12.201	Canada
Motor and driven equipment	6.3.10					X	4.3.5.5, 4.4.7, 4.7.2, 4.7.3	
Field installed *components*	6.3.11					X	4.12.1, T.4.12.1	X
Field installed *enclosure* bonding means	S.6.3.9.200		X				S.4.4.4.2.200	USA
Information for intended use	6.4.1, S.6.4.1					X	4.1	X
Adjustment	6.4.2					X	4.2	
Isolating device and disconnects	6.4.3.2	X	X	X		X	4.1, 4.2	
Hot surface	6.4.4	X				X	4.6.5.3, 5.2.4.13.1	X
Control and device marking	6.4.5		X			X	4.3	X
Stability for floor-standing *BDM/CDM/PDS*	6.4.6					X	4.12.5	
More than one factory	T.6.4.200	X						Canada
Miscellaneous	T.6.4.202	X						Canada
Removeable covers	S.6.5.1	X					S.4.12.201.10.1 e)	USA
Manufacturing date [d]	6.5.1.2	X	X				4.1	
Safety information	6.5.1.3					X	4.1	
Capacitor discharge	6.5.2	X	X	X		X	4.4.9, 4.5.2.2	X
Special operation mode – Auto restart/bypass connection	6.5.3					X	4.1	X
Other hazards	6.5.4					X	4.1, 4.2	
Live heatsink (and other parts)	S.6.5.4	ON PART						USA
BDM/CDM/PDS with multiple sources of supply	6.5.5	X				X	4.8	X
PT/CT connection	6.5.6		X			X	4.1, 4.2	X
Access conditions for *high-voltage BDM*/CDM/PDS during maintenance	6.5.7					X	4.4.10	

[a] Location: 1. On enclosed *BDM/CDM*, visible when the *enclosure cover* is on and the *door* is closed (see 6.4.3).

2. On *open type* or enclosed *BDM/CDM,* visible when opening a *door* or removing a *cover* (see 6.4.3).

3. On *open type BDM/CDM*, separate self adhesive label shipped with the device.

4. On packaging.

5. Installation, user's and/or maintenance manuals.

For marking locations 1, 2 and 3, more than one X means that anyone of the locations with an X can be used.

[b] The installation, user's and maintenance manuals may be combined as appropriate and, if acceptable to the customer, may be supplied in electronic format.

[c] When more than one of any product is supplied to a single customer, it is not necessary to supply a manual with each unit.

[d] For *open type BDM/CDM*, see 6.2.1.6.

[e] Marking of *accessories* not supplied with the *BDM/CDM/PDS* shall follow the marking instructions in 6.2.2.

[f] Parts not assembled to the *BDM/CDM/PDS* shall be marked according to 6.3.7.4.2 d).

[g] Information may be on the product or in the user manual, but if located only in the user manual, the marking of 6.1.3 applies.

[h] When indicated with an X, the information is applicable in the USA and Canada. Rows with clause references only to Annex S or Annex T are applicable only in the USA or Canada.

6.1.2 Documentation in electronic form

If documentation is provided in electronic format only, information shall be provided on the product itself or in an information sheet

- where to download this documentation (for example URL), and
- where a hard copy of the documentation can be ordered.

Where a URL is provided, this shall be in human-readable form. A machine readable code may also be provided as an optional addition.

NOTE An example for a machine readable code is QR code.

A warning shall be provided on the *BDM/CDM/PDS* by the symbol ISO 7010-M002:2011-05 (see Table C.1).

Where marking or information is provided in electronic form in accordance with location designation "5" as noted in footnote [b] of Table 48, the following marking or equivalent is provided on the device or on an information sheet provided with the *BDM/CDM/PDS* which shall be removed to install or connect the *BDM/CDM/PDS*. If the marking is provided on the device, it shall state:

> "WARNING – Consult product manual before installation or operation of the *BDM/CDM/PDS*."

When this is provided on an information sheet, that information sheet shall state:

> "WARNING – Operation of this equipment requires detailed installation and operation instructions provided in the installation/operation manual intended for use with this product. This information is provided on an electronic storage device included in the container this *BDM/CDM/PDS* was packaged in. It should be retained with this *BDM/CDM/PDS* at all times. A hard copy of this information may be obtained from the manufacturer (*the manufacturer adds the method they utilize to provide this hardcopy, i.e. phone number, address, web page, etc.)*".

6.1.3 Installation Instructions

Where information is allowed to be on the product or in the installation manual and is only provided in the installation manual, the following marking or equivalent is provided on the device or on a printed information sheet provided with the *BDM/CDM/PDS*:

> "WARNING – Operation of this equipment requires detailed installation and operation instructions provided in the installation/operation manual intended for use with this product"

or the mandatory action symbol ISO 7010-M002:2011-05 (see Table C.1).

NOTE In the USA and Canada, the mandatory action symbol ISO 7010-M002:2011-05 is not recognized.

6.2 Information for selection

6.2.1 General

6.2.1.1 General

As required in 4.1, each part of a *PDS* that is supplied as a separate product shall be provided with information for the intended use relating to its function, electrical characteristics, and intended environment (see 6.3.3) so that its fitness for purpose and compatibility with other parts of the *PDS* can be determined. For *BDM/CDM*, this information includes, but is not limited to, 6.2.1.2, 6.2.1.3, 6.2.1.4, 6.2.1.5 and 6.2.1.6.

6.2.1.2 Identifying the product

a) the name or trademark of the manufacturer, supplier or importer;

b) catalogue number or equivalent.

6.2.1.3 Electrical ratings for each *port*

a) maximum nominal input voltage;

b) maximum nominal output voltage;

c) maximum nominal output current (see 5.2.3.12) or nominal output power rating;

   NOTE 1 In the USA, nominal output power rating is in horsepower (see Table S.29 and Table S.30). If the rating is in current and power, the current and power values in Table S.29 and Table S.30 are used.

   NOTE 2 In Canada, nominal output power rating is in horsepower (see Table T.12 and Table T.13). If the rating is in current and power, the current and power values in Table T.12 and Table T.13 are used.

   NOTE 3 As part of the voltage rating, in the USA the voltage rating is either straight voltage rating, for example 480 V AC which represents a phase earthed TN-*system*, or slash voltage rating, for example 480/277 V AC which represents a neutral earthed TN-*system*.

d) duty cycle rating for *BDM/CDM/PDS* designed to operate intermittently (see 5.2.3.10);

   NOTE 4 IEC TR 61800-6 provides information about duty cycles ratings for *BDM/CDM/PDS* and IEC 61800-2:2021, 5.3.3.3, for information about *overcurrent* ratings for *BDM/CDM/PDS.*

e) maximum nominal input current RMS for dimensioning overload protective elements and wiring;

f) number of phases (e.g. 3 AC);

g) nominal frequency range (e.g. 50 Hz to 60 Hz);

h) protective class (I, II, III) see 6.3.9.2;

i) a DVC As circuit shall be durably marked where visible after installation to indicate the class of supply and its electrical rating (for example, 30 Vac, DVC As), or equivalent; and

j) a DVC As circuit intended to be supplied from an external transformer or power source in the field shall be marked "DVC As" next to the supply terminal of the *DVC As* circuit (for example, 30 Vac, *DVC As*), or the equivalent.

6.2.1.4 Supplementary information for each *port*

a) multiple rated equipment;

b) *DVC* classification according to 4.4.2.1;

c) for a *DVC As* circuit not evaluated for use in wet or salt water-wet locations, one of the following information, whichever is applicable according to Table 20, or equivalent wording:
   - "Not for use in wet locations"; or
   - "Not for use in salt water-wet locations";

d) electrical overvoltage category (see 4.4.7.1.4);

e) the type of electrical supply system (e.g. TN, IT, etc.) to which the *BDM/CDM/PDS* may be connected (see 4.4.7.1.5);

f) thermal derating characteristics for operation at an altitude above 1 000 m or by increased ambient temperature;

g) short-circuit current rating(s) in terms of
   - *conditional short-circuit current* (I_{cc}) and minimum required *prospective short-circuit current* $I_{\mathrm{cp,mr}}$ and the characteristics of the *short-circuit protective device* in accordance with 4.3.2.2,
   - available *output short-circuit current* in accordance with 4.3.2.3,
   - protective device characteristics, in accordance with 4.3.2 and 5.2.4.5,
   - combined input and output power *port*s 4.3.2.4,
   - supply requirements of the load (if applicable), and
   - field supply for DC motors (if applicable).

6.2.1.5 Liquid cooled *BDM/CDM/PDS*

As required in 4.7.4, the following information shall be provided for liquid cooled *BDM/CDM/PDS*:

a) liquid coolant type;

b) nominal operating pressure;

c) maximum operating pressure.

6.2.1.6 General *BDM/CDM/PDS* marking

a) intended use (see 4.1);

b) permitted accessories (see 4.1);

c) specific auxiliary equipment (see 4.1);

d) reference(s) to relevant standard(s) for manufacture, test, or use;

e) reference to documentation for installation, use and maintenance.

The information shall be limited to that which is essential for correct selection to be made, and should relate to specific equipment. If information covers a number of product variants, it shall be readily possible to distinguish between them.

For *open type BDM/CDM*, the marking on the *BDM/CDM* is not required to be visible when mounted side by side or next to other devices.

For *BDM/CDM/PDS* intended for use in various applications that require different wiring arrangements with corresponding different electrical ratings, the electrical ratings in 6.2 may be provided in literature supplied with the *BDM/CDM/PDS* when the *BDM/CDM/PDS* is marked:

"Multiple rated equipment. See instruction manual."

or with an equivalent statement.

6.2.2 Instructions and markings pertaining to *accessories*

As required in 4.1, the *BDM/CDM/PDS* markings shall include identification of an *accessory* to be attached in the field, or a reference to a separate publication that identifies all such *accessories*. For *BDM/CDM/PDS* such as an open device for which the required marking is on a separate sheet, the *accessory* information may also be on the separate sheet.

Accessories designed for an existing product shall be marked with the identification of the *BDM/CDM/PDS* on which it is intended to be used.

Accessories not shipped from the factory in the same carton as the *BDM/CDM/PDS* with which it is intended to be used shall be plainly marked with the following:

a) manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product is identifiable;
b) catalog number or equivalent;
c) other information, as specified in 6.3 to 6.5.

6.3 Information for installation and commissioning

6.3.1 General

As required in 4.1, safe and reliable installation is the responsibility of the installer, machine builder, and/or user. The manufacturer of any part of the *BDM/CDM/PDS* shall provide information to support this task. This information shall be unambiguous, and may be in diagrammatic form.

6.3.2 Mechanical considerations

As required in 4.1, the following information shall be provided:

a) IP rating for enclosed *BDM/CDM/PDS* in 4.12.1*;*

   NOTE 1 In lieu of the IP rating, in the USA the environmental rating in accordance with S.4.12 is used. If the environmental rating is Type 4X indoor use only, the letters of the marking are legible and of the same font and height.

   NOTE 2 In lieu of the IP rating, in Canada the environmental rating in accordance with T.4.12.1 is used.

b) dimensional drawing;
c) mounting drawing;
d) mass information;
e) top surface(s), when required in 4.4.3.3.5.1 or 4.4.3.3.5.2.

For *pluggable equipment type A* enclosed *BDM/CDM/PDS,* marking of the IP rating is not mandatory on the product.

For *BDM/CDM/PDS* weighing 18 kg or less, marking of the mass information is not mandatory on the product.

6.3.3 Environment

As required in 4.1, the manual shall specify the following environmental conditions for operation, transportation and storage in accordance with 4.9:

a) climatic (*ambient temperature*, humidity conditions, altitude, ultra-violet exposure, etc.);
b) mechanical (vibration, shock, drop, topple, etc.);

c) *pollution degree* for which the *BDM/CDM/PDS* has been designed, when required in 4.4.7.1.3;

d) requirement for heating to prevent condensation, when required in 4.4.7.1.3.

NOTE Environmental categories as specified in IEC 60721 (all parts) can be used where appropriate.

6.3.4 Handling and mounting

In order to prevent injury or damage as required in 4.2, the installation documents shall include warnings of any hazards which can be experienced during installation. Where necessary, instructions shall be provided for

a) packing and unpacking,

b) moving,

c) lifting,

d) strength and rigidity of mounting surface,

e) fastening, and

f) provision of adequate access for operation, adjustment and maintenance.

6.3.5 *Enclosure* temperature

When surface temperatures of the *BDM/CDM/PDS,* close to mounting surfaces, exceed the limit of 4.6.5.3, the installation manual shall contain a warning to install the *BDM/CDM/PDS* to non-combustible material.

The following marking or equivalent shall appear:

> "Suitable for mounting on concrete or other non-combustible surfaces only".

See also 6.4.4.

6.3.6 Open type *BDM/CDM*

6.3.6.1 Fire protection for *open type BDM/CDM*

When required by 4.6.4.3 or 4.6.5, the installation manual shall include the following warning text or equivalent:

> "This open type *BDM/CDM* does not provide comprehensive mitigation for fire hazards. It is intended to be installed inside a supplementary *enclosure* or in a *restricted-access area* which provides appropriate protection against spread of fire."

If *open type BDM/CDM* is tested according to 5.2.4.1 3), the minimum size and ventilation method for the *enclosure* shall be described.

6.3.6.2 Protection against electric shock not provided by *enclosure*s or barriers

When required by 4.4.3.3.4, the installation manual shall include the following warning text or equivalent:

> "This open type *BDM/CDM* does not provide protection against direct contact to *hazardous live part*s. It is intended to be installed inside a supplementary *enclosure* or in a *restricted-access area* which provides appropriate protection against electric shock."

6.3.6.3 Operating temperature

6.3.6.3.1 Operating *ambient temperature*

For enclosed *BDM/CDM/PDS* where the maximum *ambient temperature* is less than required in Table 20, a marking is required.

NOTE In the USA and Canada, the maximum *ambient temperature* is required to be marked in location 1 of Table 48, if the *ambient temperature* rating is less than 40 °C. If the *ambient temperature* rating is more than 40 °C, the rating is required to be in location 5 of Table 48. If the *ambient temperature* rating is 40 °C, no marking or instruction is required.

6.3.6.3.2 Operating *surrounding air temperature*

An *open type BDM/CDM* evaluated in accordance with 5.2.3.10 shall be marked

"Maximum *surrounding air temperature* (*open type*)__°C".

6.3.7 Connections

6.3.7.1 General

Any particular cable and connection requirements shall be identified in the installation and maintenance manuals as required in 4.11.3.

Information shall be provided to enable the installer to make safe electrical connection to the *BDM/CDM/PDS*. This shall include information for protection against hazards (for example, electric shock, availability of energy and special wiring *system*s) that may be encountered during installation, operation or maintenance.

6.3.7.2 Interconnection and wiring diagrams

As required in 4.1 and 4.2, the installation and maintenance manuals shall include details of all necessary connections, together with a suggested interconnection diagram as required in 4.11.8.

6.3.7.3 Conductor (cable) selection

The installation manual shall define the voltage and current levels for all field wiring terminals of the *BDM/CDM/PDS*, together with cable *insulation* requirements. These shall be worst-case values, taking into account short-circuit and overload conditions and the possible effects of non-sinusoidal currents, as required in 4.11.2.

6.3.7.4 Identification and other details of *field wiring terminals*

6.3.7.4.1 Identification of *field wiring terminals*

The identification of all *field wiring terminals* shall be marked on the *BDM/CDM/PDS*, either directly or by a label attached close to the terminals (see 4.11.5 and 4.11.11.3).

The installation and maintenance manuals shall identify all external terminals relating to circuits protected by one of the methods of 4.4.6.5.3 for connection to external *PELV* circuits or *SELV* circuits.

If the *protective earthing* terminal is not in proximity to its associated input or output terminals, description is required to ensure proper earthing of the *system*. See 4.11.11.3.

A terminal for the connection of the neutral conductor shall be readily distinguishable by location and/or marking or colour, as required by 4.11.5, from the other terminals. Alternatively, proper identification of the terminal for the connection of the neutral conductor shall be clearly shown in some other manner, such as on an attached wiring diagram.

6.3.7.4.2 Other details of *field wiring terminals*

To ensure a safe installation, the documentation shall specify the following in a), b), c), d) and e) as applicable:

a) Terminal characteristics
   – range of acceptable conductor sizes and types (solid or stranded) for all terminals (see 4.11.11.2);
   – maximum number of conductors which can simultaneously be connected in parallel per terminal;
   – size of the fasteners (see d)).

   NOTE 1 In the USA, conductor type, number per terminal, and size of fasteners are not required. If a wiring terminal is not intended to receive a conductor one size larger than that specified in S.4.11.11.2, then the documentation must be marked to restrict its use to the smaller size conductor. Otherwise conductor size is not required.

b) Tightening torque value
   – nominal or the range of tightening torque value;
   – required strength of bolts and nuts.

   NOTE 2 In the USA, the specified tightening torque must not be less than 90 % of the value employed in the static heating test as specified in the requirements in the Standard for Wire Connectors, UL 486A-486B or the Standard for Equipment Wiring Terminals for Use With Aluminum and/or Copper Conductors, UL 486E.

   NOTE 3 In the USA, the value of tightening torque is not required to be 90 % of the value specified when the connector is investigated in accordance with UL 486A-486B or UL 486E, with the lesser assigned torque value.

   NOTE 4 In the USA, a *field wiring terminal* intended only for the connection of a *control circuit* conductor is not required to be marked with a value of tightening torque when tested in accordance with the applicable requirements in UL 486A-486B or UL 486E, with a value of tightening torque of 7 lbf·in (0,8 Nm).

c) Cable type and temperature
   – whether the terminals are suitable for connection of copper, aluminium and/or copper-clad aluminum conductors;
   – the insulation temperature rating requirements for the conductor or cable based on the results of the temperature test in 5.2.3.10. See 4.11.11.2.

   NOTE 5 In the USA and Canada, field wiring terminals with aluminum bodied connectors or intended for use with aluminum wire must be marked AL7CU or AL9CU for 60 °C or 75 °C wire *insulation*.

   NOTE 6 In the USA and Canada, *BDM/CDM/PDS* must be marked to indicate the temperature rating, 60 °C only, 60/75 °C, or 75 °C only, used in the evaluation of the power *field wiring terminal*s. *Control circuit* terminals are not required to be marked to indicate the temperature rating.

d) *Accessories* for wire connection
   – the stripping length of the wire;
   – specific ring lugs, ferrules, leads, wire binding screws or pressure wire connectors;
   – pressure wire connector or component terminal accessory kits;
   – wiring accessories such as nuts, bolts, spring washers;
   – accessories for the securement, routing and fixing of cables.

e) Wire terminal components
   – when wire terminal components are not provided on the equipment as shipped, the documentation shall state which component terminal kits are intended for use with the equipment;
   – when parts of terminals (e.g. cable lugs or removable part of two-part connectors) are not provided on the equipment as shipped, the documentation shall state which terminal kits are intended for use with the equipment, or standard off the shelf parts of the terminals.

6.3.7.5 Mains plug and socket-outlets

When required in 4.11.7, mains plug and socket-outlets accepting standard mains plugs shall be marked with the voltage if it is different from the *mains supply* voltage. If the mains socket-outlet is for use only with specific *BDM/CDM/PDS*, it shall be marked to identify the *BDM/CDM/PDS* for which it is intended. If not, the maximum rated current or power shall be marked, or symbol ISO 7010-W001:2011-05 shown in Table C.1 placed beside the mains socket-outlet with the full details included in the documentation.

6.3.8 Commissioning

If *commissioning tests* are necessary to ensure the electrical and thermal safety of a *BDM/CDM/PDS*, information to support these tests shall be provided for each part of the *PDS*. This information can depend on the specific *installation*, and close cooperation between manufacturer, installer and user can be required.

As required in 4.1 and 4.2, commissioning information shall include references to hazards that might be encountered during commissioning, for example those mentioned in 6.4 and 6.5.

6.3.9 Protection requirements

6.3.9.1 *Accessible part*s and *accessible circuit*s

6.3.9.1.1 General

When required by 4.4.3.3.2 for use in *service-access areas*, the installation and maintenance manuals shall identify any conductive *accessible parts* at voltages greater than *DVC As*, and shall describe the *insulation* and separation provisions required for protection.

The manuals shall also indicate the precautions to be taken to ensure that the safety of *DVC As* connections is maintained during installation.

Where a hazard is present after the removal of a *cover* of an enclosed *BDM/CDM/PDS* (see 4.4.3.3.2), a warning label shall be placed on the *BDM/CDM/PDS*. The label shall be visible before the *cover* is removed.

NOTE If the warning label is placed on a *cover*, it is no longer mandatory to be visible when the *cover* is removed.

The manual of a *BDM/CDM/PDS* shall state the maximum voltage allowed to be connected to each *port*.

The manuals shall provide instructions for the use of *PELV* circuits or *SELV* circuits within a *zone of equipotential bonding*.

6.3.9.1.2 Requirements for alternate methods in *service-access area*

To ensure the safety of personnel is maintained while performing maintenance and/or servicing prescribed by the manufacturer – see 4.4.3.3.2 b) –, the installation and maintenance manual shall be provided to allow precautions to be planned and safe work achieved by the maintenance personnel, if the equipment is energized. This manual shall

a) provide detailed instructions for any maintenance or servicing required in a *service-access area* which requires a tool or key to enter,
b) expressly highlight any hazardous condition that exists within the area of the product where servicing or maintenance is required, and
c) include the specific location of any potentially hazardous energy whether electrical, mechanical, etc.

6.3.9.2 Protective class

6.3.9.2.1 General

The installation manual shall declare the protective class specified for the *BDM/CDM/PDS* as required by 4.4.6 and 4.4.4.3.3 and the product shall be marked according to the requirement of 6.3.9.2.2, 6.3.9.2.3 and 6.3.9.2.4.

6.3.9.2.2 *Protective class I BDM/CDM/PDS*

Terminals for connection of the *PE conductor* as required by 4.4.4.3.2 and 4.11.5 shall be clearly and indelibly marked with one or more of the following:

a) symbol IEC 60417-5019:2006-08 (see Table C.1);

b) letters PE;

c) colour coding green or green-and-yellow.

NOTE In the USA and Canada, the symbol IEC 60417-5017:2006-08 or symbol IEC 60417-5019:2006-08 or the wording "G," "GR," "GRD," "Ground," "Grounding," or similar designation may be used. A wire binding screw intended for the connection of a field-installed equipment *PE conductor* must have a green coloured head that is hexagonal, slotted, or both.

When requested by 4.11.5, the documentation shall specify clear instruction on the location of the *PE*-terminal and correct connection to the terminal.

6.3.9.2.3 *Protective class II BDM/CDM/PDS*

BDM/CDM/PDS of *protective class II* shall be marked with symbol IEC 60417-5172:2003-02 (see Table C.1). Where such *BDM/CDM/PDS* has provision for the connection of an earthing conductor for functional reasons (see 4.4.6.3), this means of connection shall be marked with symbol IEC 60417-5018:2011-07 (see Table C.1).

6.3.9.2.4 *Protective class III BDM/CDM/PDS*

BDM/CDM/PDS of *protective class III* shall be marked with symbol IEC 60417-5180:2003-02 (see Table C.1).

No marking is required on the product.

6.3.9.3 *Protective equipotential bonding* circuit

The *protective equipotential bonding* circuit in 4.4.4.2 shall be marked as follows.

a) For the means of connection for the external *PE-conductor* in 4.4.4.3.2, see 6.3.9.2.2.

   NOTE 1 Following text is copied and modified from IEC 60204-1:2016, 13.2.2.

b) The internal *protective equipotential bonding* conductor shall be readily distinguishable from other conductors by shape, location, marking, or colour.

c) Where they can be easily identified by its shape, position, or construction (for example a braided conductor, uninsulated stranded conductor), no additional marking is required.

d) When identification is by colour alone, the bicolour combination green-and-yellow shall be used throughout the length of the conductor, or where the insulated conductor is not readily accessible or is part of a multicore cable, colour coding throughout its length is not necessary. However, where the conductor is not clearly visible throughout its length, the ends or accessible locations shall be clearly identified by

   - the symbol IEC 60417-5017:2006-08,
   - the bicolour combination green-and-yellow, or
   - markings, if explained in the documentation.

NOTE 2 Following text copied and modified from IEC 62368-1:2018, F.3.6.1.1.

e) However, where terminals for the connection are provided on a component or sub-assembly, either the symbol IEC 60417-5017:2006-08 or the symbol IEC 60417-5019:2006-08 is permitted.

When required in 4.4.4.2.1, where screws for connecting the *protective equipotential bonding* are used for other purpose, this shall be specified in the documentation.

6.3.9.4 *Touch current* or high leakage current

6.3.9.4.1 General

The documentation shall specify if one or more of the solutions mentioned in 4.4.4.3.3 are applicable for the *BDM/CDM/PDS*.

6.3.9.4.2 *Touch current*

Where the *touch current* exceeds the limits given in 4.4.4.3.3, this shall be stated in the installation and maintenance manuals. In addition, a warning symbol ISO 7010-W001:2011-05 or ISO 7000-0434a:2004-01 or ISO 7000-0434b:2004-01 (see Table C.1) shall be placed on the product, and a notice shall be provided in the installation manual that the minimum size of the *PE conductor* shall comply with the local safety regulations for high *touch current BDM/CDM/PDS*.

When required by 4.4.4.3.3, the maximum number of interconnected *BDM/CDM/PDS* shall be stated in the installation manual.

6.3.9.4.3 High leakage current

If the *PE conductor* current exceeds the limits given in 4.4.4.3.4, this shall be stated in the installation and maintenance manuals. In addition, a warning symbol ISO 7010-W001:2011-05 or ISO 7000-0434a:2004-01 or ISO 7000-0434b:2004-01 (see Table C.1) shall be placed on the product, and a notice shall be provided in the installation manual that connection of simultaneously conductive *accessible parts* in the vicinity of the *BDM/CDM/PDS* to the *protective equipotential bonding* circuit of the *BDM/CDM/PDS* is required.

The installation manual shall specify if one or more of the solutions mentioned in 4.4.4.3.4 are applicable for the *BDM/CDM/PDS*.

6.3.9.5 Compatibility with RCD

The installation and maintenance manuals shall indicate compatibility with RCDs (see 4.4.8). When 4.4.8 b) applies, a notice and the warning symbol ISO 7010-W001:2011-05 or ISO 7000-0434a:2004-01 or ISO 7000-0434b:2004-01 (see Table C.1) shall be provided in the user manual, and the symbol shall be placed on the product. The caution notice shall be the following or equivalent:

> "This product can cause a DC current in the *PE conductor*. Where a residual current-operated protective device (RCD) is used for protection against electric shock, only an RCD of Type B is allowed on the supply side of this product. All upstream RCD, up to the supply transformer, shall be of Type B."

See 6.4.3 for general requirements for labels, signs and signals.

NOTE In the USA and Canada, the requirement of 6.3.9.5 does not apply.

6.3.9.6 External protection means

6.3.9.6.1 General

Where external protection means are necessary to protect against hazards, they shall be specified in the installation and maintenance manual.

6.3.9.6.2 Protective devices

In cases where external protective devices are required, the required types or the characteristics of *overcurrent* protective device (see also 5.2.4 and 4.3.2.2, 4.3.2.3) shall be specified.

For *open type BDM/CDM,* the manufacturer shall state if the protective device shall be installed in the same end use *enclosure* as the *BDM/CDM* (see 5.2.4.6).

6.3.9.6.3 Protection according to IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017, Clauses 411 or 415

When the *BDM/CDM/PDS* complies with the requirement of 4.4.4.4.1 and 4.4.4.4.2 or 4.4.4.4.3, the *BDM/CDM/PDS* manufacturer shall state

a) the types or the characteristics of the protective devices (see 4.4.4.4.2) when used to comply with test in 5.2.4.5.3,
b) that an electronic protection circuitry meets the requirements of IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017, Clause 411 (see 4.4.4.4.3 1)), when used to comply with test in 5.2.4.5.3, or
c) that the requirements of the supplementary *protective equipotential bonding* (see 4.4.4.4.3 2)) of the motor or external load complies with IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017, Clause 415.

In addition, the conditions for the application of the above mentioned protective measures shall be specified. This includes, for example,

d) the limitation of the cable length to the motor,
e) the minimum conductor cross-section of the cable(s) to the motor (line conductor, *PE conductor*),
f) the cable type, and
g) the type of the supply earthing *system*.

NOTE Initial and periodic verification including the verification method is required from IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017, Annex D.

6.3.9.6.4 Surge protective devices

If SPDs are required for compliance with 4.4.7.2.3 and 4.4.7.2.4, the user manual shall provide information on the proper selection of *SPDs* to be installed in the fixed *installation* to ensure correct reduction of overvoltages.

6.3.9.7 Motor overload protection and overtemperature protection

6.3.9.7.1 *BDM/CDM* not incorporating internal *electronic motor overload protection* and overtemperature protection

If the *BDM/CDM* does not incorporate electronic motor overload or motor overtemperature protection, the installation manual shall indicate that these motor protection features are not provided. See 4.3.5.1 e).

6.3.9.7.2 *BDM/CDM* incorporating internal *electronic motor overload protection* and overtemperature protection

If required by 4.3.5.2, the installation and maintenance manuals of *BDM/CDM* incorporating internal overload protection shall provide all the following information:

a) protection in multiple of current setting;

b) tripping time;

c) instructions for adjustment.

If the internal *electronic motor overload protection* has *thermal memory retention* (see 4.3.5.3), the installation and maintenance manuals of *BDM/CDM* shall provide information about the behaviour. When the *thermal memory retention* is adjustable, the manuals shall be provided with instructions for adjustment.

If the internal *electronic motor overload protection* does not have *thermal memory retention* (see 4.3.5.3), this information shall be provided in the installation and maintenance manuals.

If the internal *electronic motor overload protection* is speed sensitive (see 4.3.5.4), the installation and maintenance manuals of *BDM/CDM* shall provide information about the behaviour. When the speed sensitivity is adjustable, the manuals shall be provided with instructions for adjustment.

If the internal *electronic motor overload protection* is not speed sensitive (see 4.3.5.4), this information shall be provided in the installation and maintenance manuals.

6.3.10 Motor and driven equipment

6.3.10.1 Motor selection

Where necessary for *BDM/CDM*, information on suitable motor specifications shall be provided according to IEC 60034-1:2022. The possible influence on motor *insulation* of reflections of the PWM output waveform shall be taken into consideration.

6.3.10.2 Motor integrated sensors

To ensure that the *insulation system* of the *BDM/CDM/PDS* designed according to 4.4.7 is not violated, the installation manual shall define the protection requirements for sensors integrated into the motor. See also 4.3.5.1 c).

6.3.10.3 Critical torsional speeds

When required by 4.7.2, the *PDS* manufacturer shall provide all relevant motor information to enable critical torsional speeds to be identified.

NOTE See also IEC 61800-2:2021, 5.13.

6.3.10.4 Transient torque analysis

When required by 4.7.3, the *PDS* manufacturer shall provide all relevant electrical and mechanical information to enable transient torque analysis to be performed.

NOTE See also IEC 61800-2:2021, 5.13.

6.3.11 Field installed *components*

Enclosures intended for field installation of *components* critical to the environmental integrity of the *enclosure* shall be marked or provided with instructions that identify the *BDM/CDM/PDS* necessary to maintain the environmental integrity of the *enclosure*. This may be accomplished by identifying the necessary IP rating or by identifying the specific manufacturer and model number of the field installed *BDM/CDM/PDS*.

NOTE 1 In lieu of the IP rating, in the USA the environmental rating in accordance with S.4.12.201.2 is used. If the environmental rating is type 4X indoor use only, the letters of the marking must be legible and of the same font and height.

NOTE 2 In lieu of the IP rating, in Canada the environmental rating in accordance with T.4.12.1 is used.

6.4 Information for intended use

6.4.1 General

As required in 4.1, the user's manual shall include all information regarding the safe operation of the *BDM/CDM/PDS*. In particular, it shall identify any

a) hazardous materials,
b) risks of electric shock,
c) overheating,
d) explosion, and
e) excessive acoustic noise, etc. (see 4.10.2).

6.4.2 Adjustment

As required in 4.2, the user's manual shall give details of all safety-relevant adjustments intended for the user. The identification or function of each control or indicating device and *overcurrent* protective devices shall be marked adjacent to the item. Where it is not possible to do this on the product, the information shall be provided pictorially in the manual.

Maintenance adjustments that affect safety shall be described in the manual; it shall be made clear that these adjustments require a qualified person.

Clear warnings shall be provided where excessive adjustment could lead to a hazardous state of the *BDM/CDM/PDS*.

Any special equipment necessary for making adjustments shall be specified and described.

6.4.3 Labels, signs, symbols and signals

6.4.3.1 General

Labelling shall be in accordance with good ergonomic principles so that notices, controls, indications, test points, *overcurrent* protective devices, etc., are sensibly placed and logically grouped to facilitate correct and unambiguous identification.

All safety related *BDM/CDM/PDS* caution and warning labels required for location 2 according to Table 48 indicating a hazard shall be located so as to be visible after installation or readily visible by opening a *door* or removing a *cover* when *BDM/CDM/PDS* is installed as intended including side-by-side with specified *clearance*.

Where a symbol is used, the information provided with the *BDM/CDM/PDS* shall contain an explanation of the symbol and its meaning.

Labels shall

a) wherever possible, use international symbols as given by ISO 3864-1, ISO 7000 or IEC 60417,
b) if no international symbol is available, be worded in an appropriate language or in a language associated with a particular technical field,
c) be conspicuous, legible and durable,
d) be concise and unambiguous, and
e) state the hazards involved and give ways in which risks can be reduced.

When instructing the person(s) concerned as to

f) what to avoid: the wording should include "no", "do not", or "prohibited";
g) what to do: the wording should include "shall", or "must";
h) the nature of the hazard: the wording should include "caution", "warning", or "danger", as appropriate;
i) the nature of safe conditions: the wording should include the noun appropriate to the safety device.

Safety signs shall comply with ISO 3864-1 except that any other colour combination including monochrome with the contrast requirement as specified by ISO 3864-4:2011, Clause D.2, may be used. For guidance of determination of contrast, see Clause C.2.

The signal words indicated hereinafter shall be used and the following hierarchy respected:

j) "DANGER" indicates a hazardous situation which, if not avoided, will result in death or serious injury, for example: "High voltage".
k) "WARNING" indicates a hazardous situation which, if not avoided, could result in death or serious injury, for example: "This surface can be hot."
l) "CAUTION" indicates a hazardous situation which, if not avoided, could result in minor or moderate injury, for example: "Some of the tests specified in this document involve the use of processes imposing risks on persons concerned."

The signal word hierarchy shall be observed as a minimum. For example, "Danger" may be used instead of either "Warning" or "Caution", but not vice versa.

Danger, warning and caution markings on the *BDM/CDM/PDS* shall be prefixed with the signal word "DANGER", "WARNING", or "CAUTION" as appropriate in letters not less than 3,2 mm high. The remaining letters of such markings shall not be less than 1,6 mm high.

If the danger, warning or caution marking is on a visible surface whose width and length are both 20 cm or more, the signal words shall have letters not less than 5 mm high. The remaining letters of such markings shall not be less than 2,5 mm high.

Danger, warning and caution markings shall not be located solely on a part that is removable unless removal of the part impairs the operation or appearance of the *BDM/CDM/PDS*.

NOTE ANSI Z535 (all parts) can be useful for further information on markings.

Danger, warning and caution markings intended to instruct the operator shall be legible and visible to the operator during normal operating conditions of the *BDM/CDM/PDS*.

All safety markings, labels, signs and signals applied to the product shall be evaluated as durable. Materials and the attachment method shall be suitable for the *expected lifetime* of the product when subjected to the environmental conditions the product is rated to be transported, stored, installed and operated in.

Materials are acceptable when they comply with ISO 17398.

For markings according to equivalent national safety standards, see 4.13.1.

The following marking methods are considered to comply without test:

m) moulded, die-stamped, paint-stenciled, stamped markings;

n) made of etched, lasered or engraved material that is permanently secured.

Product safety labels shall have a reasonable expected life with good colour stability, safety sign and safety information symbol legibility, and text legibility when viewed at a safe viewing distance. Choice of materials and attachment method should take into account the foreseeable environment of use and the expected life of the product.

Compliance can be demonstrated by *visual inspection* in 5.2.1 of the datasheet.

6.4.3.2 Isolating device and disconnects

As required in 4.1 and 4.2, where an isolating device is not intended to interrupt load current, a warning shall state:

DO NOT OPEN UNDER LOAD.

The following requirements apply to any supply isolating device which does not disconnect all sources of power to the *PDS*.

a) If the isolating device is mounted in an *BDM/CDM/PDS enclosure* with the operating handle externally operable, a warning label shall be provided adjacent to the operating handle stating that it does not disconnect all power to the *BDM/CDM/PDS*.

b) Where a *control circuit* disconnector can be confused with power circuit disconnectors due to size or location, a warning label shall be provided adjacent to the operating handle of the *control circuit* disconnector stating that it does not disconnect all power to the *BDM/CDM/PDS*.

c) Compliance with the requirements for *BDM/CDM/PDS* with multiple sources of supply in 6.5.5.

6.4.4 Hot surface

Where required by 4.6.5.3 or 5.2.4.13.1, the caution symbol IEC 60417-5041:2002-10 or ISO 7010-W017:2011-05 (see Table C.1) shall be marked on or adjacent to parts exceeding the touch temperature limits of Table 18.

6.4.5 Control and device marking

As required in 4.3, the identification of each control or indicating device and *overcurrent* protective devices shall be marked adjacent to the item.

Replaceable *overcurrent* protective devices shall be marked with their rating and time characteristics except for semi-conductor fuses. Where it is not possible to do this on the product, the information shall be provided pictorially in the manual.

Appropriate identification shall be marked on or adjacent to each movable connector.

Test points shall be individually marked with the circuit diagram reference.

The polarity of any polarized devices shall be marked adjacent to the device.

The diagram reference and if possible the function shall be marked adjacent to each pre-set control in a position where it is clearly visible while the adjustment is being made.

6.4.6 Stability for floor-standing *BDM/CDM/PDS*

As required in 4.12.5 for *BDM/CDM/PDS* that stands freely on the floor (floor-standing) or that are portable, measures or information shall be provided in the installation instruction to prevent physical instability including tilting.

6.5 Supplementary information

6.5.1 General

6.5.1.1 General

As required in 4.1, to ensure that maintenance of the *BDM/CDM/PDS* can be conducted in a safe manner, safety markings shall be as provided in 6.5.1.3.

6.5.1.2 Manufacturing date

As required in 4.1, the manufacturing date of the *BDM/CDM/PDS* shall be marked on the product with the date code, serial number or similar, from which the date of manufacturing can be determined.

6.5.1.3 Safety information

The manufacturer shall determine and provide safety information in the installation and maintenance manuals including, as appropriate, the following:

a) preventive maintenance procedures and schedules;
b) safety precautions during maintenance (for example, the use of earthing switches for *high-voltage BDM/CDM/PDS*);
c) location of *hazardous live parts* that can be accessible during maintenance (for example, when covers are removed);
d) adjustment procedures;
e) sub-assembly and *component* repair and replacement procedures;
f) instruction that maintenance and installation will only be performed by *skilled person*s;
g) any other relevant information.

NOTE 1 These can best be presented as diagrams.

NOTE 2 A list of special tools can be provided, when appropriate.

6.5.2 Capacitor discharge

When the requirements in 4.4.9 or 4.5.2.2 are not met, the warning symbol IEC 60417-6042:2010-11 or ISO 7010-W012:2011-05 and IEC 60417-5416:2015-04 (see Table C.1) and an indication of the minimum discharge time required for discharge under worst conditions (for example, discharge time 5 min) or

"WARNING: Risk of electric shock – Capacitor discharge time X s"

shall be located according to 6.4.3.1, the capacitor's protective barrier, or at a point close to the capacitor(s) concerned (depending on the construction). The symbol shall be explained and the time required for the capacitors to discharge after the removal of energy from the *BDM/CDM/PDS* shall be stated in the installation and maintenance manuals.

NOTE The value of the discharge time declared by the manufacturer can cover a range of *PDS* taking into account the relevant tolerances for the complete range of *PDS*.

6.5.3 Special operation mode – Auto restart/bypass connection

As required in 4.1, if a *BDM/CDM/PDS* can be configured to provide automatic restart or bypass connection, the installation, user and maintenance manuals shall contain appropriate warning statements.

6.5.4 Other hazards

As required in 4.1 and 4.2, the manufacturer shall identify (on the product, in the installation and maintenance manuals, as applicable) any *component* and material of a *BDM/CDM/PDS* which require special procedures to prevent hazards on the product.

Appropriate caution or warning label shall be placed on the product according to Table 48 and 6.4.3.1 considering the nature of hazard.

6.5.5 *BDM/CDM/PDS* with multiple sources of supply

In accordance with 4.8, where there is more than one source of supply energizing the *BDM/CDM/PDS*, information shall be provided to indicate which disconnect device or devices are required to be operated in order to completely isolate the *BDM/CDM/PDS*.

When more than one disconnect switch is required to disconnect all power within a control assembly or compartment, the assembly or compartment shall be marked according to 6.4.3.1 and 6.4.3.2 with the

a) words "Risk of electric shock – More than one disconnect switch is required to de-energize the equipment before servicing.", or equivalent, and
b) the word "WARNING", or
c) the warning symbol IEC 60417-6042:2010-11 or ISO 7010-W012:2011-05 (see Table C.1).

NOTE In Canada, the following text shall be used:

WARNING: MORE THAN ONE LIVE CIRCUIT. SEE DIAGRAM.

The marking shall be in the installation manual and

d) in a permanent location on the outside of the *BDM/CDM/PDS*, or
e) on a stationary fixed, non-removable part inside the *BDM/CDM/PDS*.

6.5.6 PT/CT connection

As required in 4.1 and 4.2, a *BDM/CDM/PDS* which provides a potential transformer (PT) supplied from high-voltage, or a current transformer (CT) supplied from a high current connection for external monitoring or control functions, shall be clearly marked on the product to show the possible hazards of voltage transients upon disconnection of the secondary circuit. The hazards shall also be described in the installation and maintenance manuals.

6.5.7 Access conditions for *high-voltage BDM/CDM/PDS* during maintenance

NOTE Isolating means according to UL 347A.

A switch that may be energized from either side shall be marked

"DANGER – Switch blades may be live when open."

This marking shall be expanded to include reference to fuses and fuseholders if applicable. See 4.4.10.2.1.5.

BDM/CDM/PDS that is not provided with an integral isolating device as indicated in 4.4.10.2 shall be marked as follows.

a) "DANGER. This equipment does not provide isolation. Separate isolating means required. See instructions for further information." The marking shall also include reference to the specific instruction manual containing this information by publication number, drawing number, or the equivalent.
b) The instructions referenced in the marking shall indicate the specific external isolating means that shall be provided, if required.
c) If the interlocking system is not provided, the instructions shall identify the interlocking kit by manufacturer and catalog number that shall be installed on the external isolating means to coordinate the interlocking system of the *BDM/CDM/PDS* with the isolating means. The interlocking kit shall include specific instructions detailing the installation of the interlock on the isolating means.

The installation and maintenance manual shall specify requirements for earthing switches and/or removable *PE conductor* of the *BDM/CDM/PDS* during maintenance.

Annex A
(normative)

Additional information for protection against electric shock

A.1 General

Clause A.2, Clause A.3 and Clause A.4 show examples of the methods used for protection against electric shock in *protective class III BDM/CDM/PDS* and *DVC As* circuits (see 4.4.2.2).

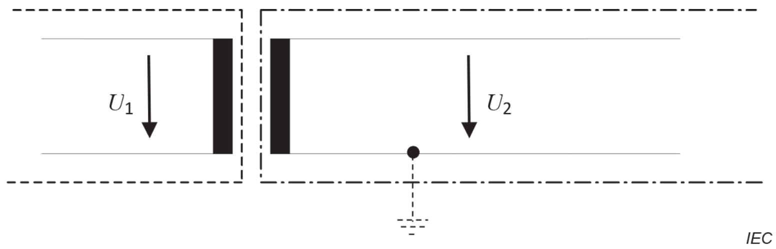
The following key applies to Figure A.1 to Figure A.3.

-------------------- *Basic protection*

–·–·–·–·–·–·–·–·– *Enhanced protection* to *adjacent circuit*s according to Table 3

A.2 Protection by means of *DVC As*

(see 4.4.2.2)



Key

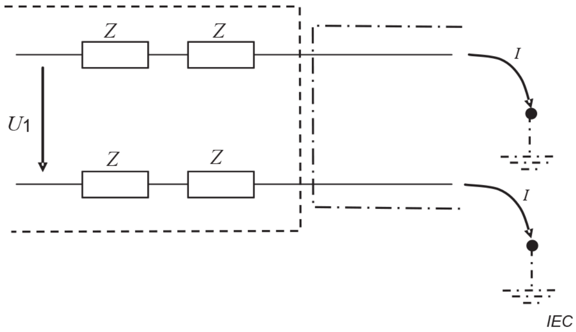
U_1 hazardous voltage, earthed or unearthed

U_2 ≤ *DVC As* from Table 2

Figure A.1 – Protection by *DVC As* with *enhanced protection*

A.3 Protection by means of *protective impedance*

(see 4.4.5.4)



Key

Z resistor

U_1 hazardous voltage, earthed or unearthed

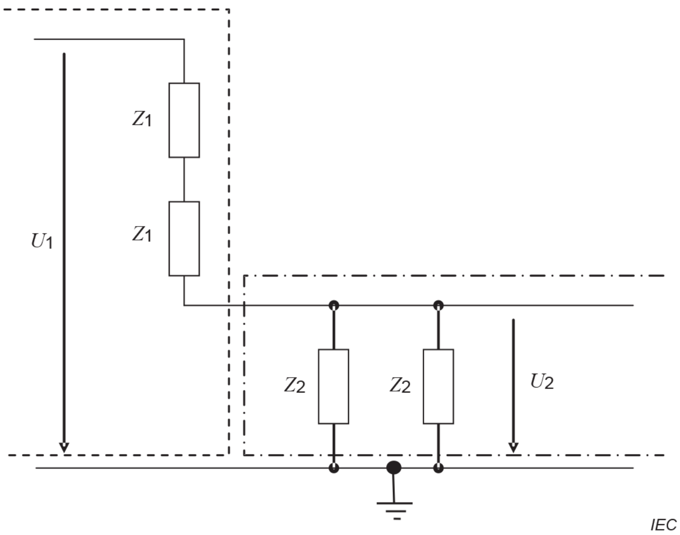
I ≤ limits in 4.4.5.4

To provide protection in *single-fault conditions*, use the following formula: $I = \frac{U_1}{Z}$

Figure A.2 – Protection by means of *protective impedance*

A.4 Protection by using limited voltages

(see 4.4.5.4)



Key

Z resistor

U_1 hazardous voltage, earthed

U_2 ≤ *DVC As* from Table 2.

To provide protection in *single-fault conditions*, use the following formulae:

$$U_2 = \frac{U_1 Z_2}{2Z_1 + Z_2} \quad \text{or} \quad U_2 = \frac{U_1 Z_2}{2(Z_1 + Z_2/2)}$$

Figure A.3 – Protection by using limited voltages

A.5 Evaluation of the *working voltage* of circuits

A.5.1 General

The decisive voltage of each circuit of the *BDM/CDM/PDS* in respect of the protective measures to be employed against electric shock is the highest voltage which occurs between any two arbitrary *live parts* within this circuit during rated worst operating conditions when used as intended.

If connection of the circuit to *PE* is provided, then the decisive voltage is the highest voltage which occurs between any arbitrary *live part* of this circuit and earth (for example circuits connected to an earthed three-phase supply).

A portion of a *DVC As* circuit may exceed the voltage limits of Table 2 when this portion is protected against direct contact according to 4.4.3.3 and the accessible portion of the *DVC As* circuit complies with the voltage limits of Table 2 under *single-fault conditions* according to 4.2. These voltages shall however still be used in the determination of *clearance*s and *creepage distance*s for the circuit under consideration to its *surroundings* in 4.4.7.4 and 4.4.7.5.

A.5.2 Classification of the *working voltage*

The limits of Table 2 are valid for nearly sinusoidal AC and nearly ripple free DC. However, in electronic power conversion circuits, curve shapes of voltages are present which are neither nearly sinusoidal AC nor ripple free DC.

In A.5.2, methods and rules are provided to classify any voltage shape into one of the *DVC* in Table 2.

In the first step, the mean value of the voltage under investigation is determined: if the mean value is zero, this voltage is considered AC *working voltage* and the rules are given in A.5.3.

NOTE The meaning of "zero" in the above sentence is a negligible mean value.

If the mean value is unequal to zero, in the second step the RMS value of the superposed ripple voltage is determined.

- If this RMS value of the ripple does not exceed 10 % of the mean value of the DC, this voltage is considered DC *working voltage* and the rules are given in A.5.4.
- If this RMS value of the ripple exceeds 10 % of the mean value of the *DC*, this voltage is considered pulsating *working voltage* and the rules are given in A.5.5.

In the third step, determination of the applicable values is done with the method set out in A.5.2 below for

- AC RMS (U_{AC}),
- AC recurring peak (U_{ACP}),
- DC mean (U_{DC}), and
- DC recurring peak (U_{DCP}).

Three cases of waveforms are considered: Figure A.4, Figure A.5 and Figure A.6 shows typical waveforms for the evaluation of *working voltage*.

A.5.3 AC *working voltage*

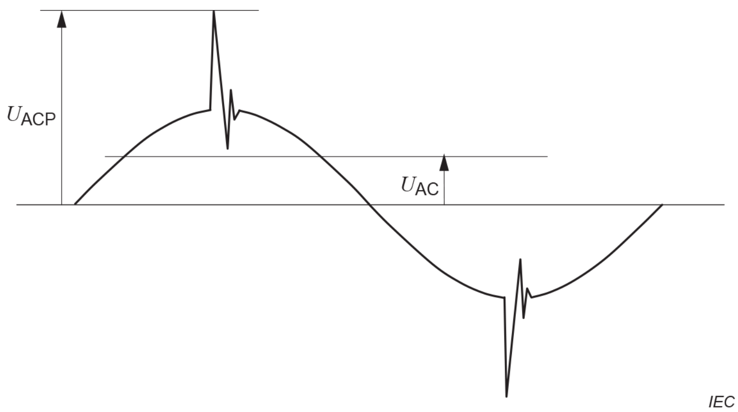


Figure A.4 – Typical waveform for AC *working voltage*

The *working voltage* has an RMS value U_{AC} and a recurring peak value U_{ACP}.

The *DVC* is that of the lowest voltage row of Table 2 starting with *DVC As* for which both of the following conditions are satisfied for the same row:

- $U_{AC} \leq U_{ACL}$;
- $U_{ACP} \leq U_{ACPL}$.

Example with values:

U_{AC} = 39 V --> is lower than U_{ACL} = 50 V --> DVC B

U_{ACP} = 91 V --> is higher than U_{ACPL} = 71 V --> DVC C

The rule for determining the *DVC* of the voltage is to select the highest *DVC*.

Result: --> this *working voltage* is *DVC C*.

A.5.4 DC *working voltage*

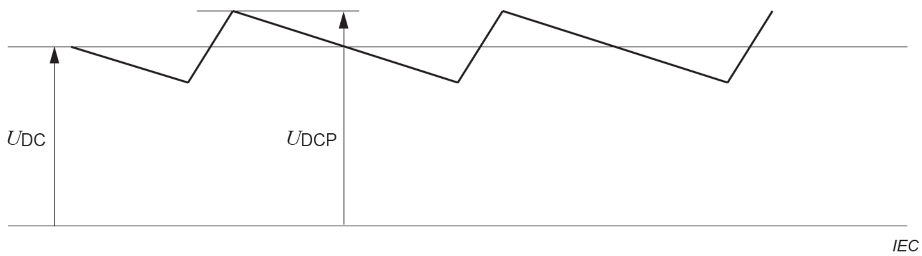


Figure A.5 – Typical waveform for DC *working voltage*

The *working voltage* has a mean value U_{DC} and a recurring peak value U_{DCP}.

The *DVC* is that of the *DVC* row of Table 2 starting with *DVC As* for which both of the following conditions are satisfied for the same row:

- $U_{DC} \leq U_{DCL}$;
- $U_{DCP} \leq 1{,}17 \times U_{DCL}$.

NOTE The value of 1,17 results from a superimposed ripple voltage on a triangle waveform with 10 % RMS value.

Example with values:

U_{DC} = 39 V --> is lower than U_{DCL} = 60 V --> *DVC As* dry

U_{DCP} = 69 V --> is lower than 1,17 × U_{DCL} = 70,2 V --> *DVC As dry*

The rule for determining the *DVC* of the voltage is to select the highest *DVC*.

Result: --> this working voltage is DVC As dry.

A.5.5 Pulsating *working voltage*

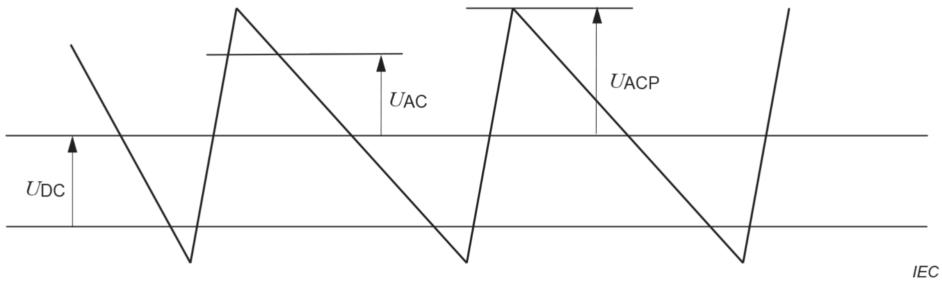


Figure A.6 – Typical waveform for pulsating *working voltage*

The *working voltage* has a mean value U_{DC}, an *AC* value U_{AC} and a recurring peak value U_{ACP}.

The *DVC* is that of the *DVC* row of Table 2 starting with *DVC As* for which both of the following conditions are satisfied for the same row:

$$\frac{U_{AC}}{U_{ACL}}+\frac{U_{DC}}{U_{DCL}}\leq 1 \quad \text{and} \quad \frac{U_{ACP}}{U_{ACPL}}+\frac{U_{DC}}{1{,}17\times U_{DCL}}\leq 1$$

Example with values:

U_{DC} = 39 V;

U_{AC} = 49 V;

U_{ACP} = 91 V.

First calculation with the limits of *DVC B:*

$$\frac{49}{50}+\frac{39}{120}\leq 1\ ?$$

0,980 + 0,325 = 1,305 --> the result is exceeding 1 --> *DVC C*

and

$$\frac{91}{71}+\frac{39}{1{,}17\times 120}\leq 1\ ?$$

1,282 + 0,278 = 1,560 --> the result is exceeding 1 --> *DVC C*

The rule for determination of *DVC* of the voltage is to select the highest *DVC*:

Result: --> this working voltage is DVC C.

A.6 The concept of protective measures according to 4.4

A.6.1 General

Protection against electric shock shall be achieved by means of

- a combination of *basic protection* according to 4.4.3 and *fault protection* according to 4.4.4, or
- *enhanced protection* according to 4.4.5.

The cases described in A.6.2 and A.6.3 are for the protection of *ordinary persons*. The protection of *skilled person*s allows reduced protection as described in 4.4.3.3.3.

In addition, only protection of *DVC As* circuits against *DVC C* and *DVC D* is covered.

A.6.2 General concept of protection against electric shock

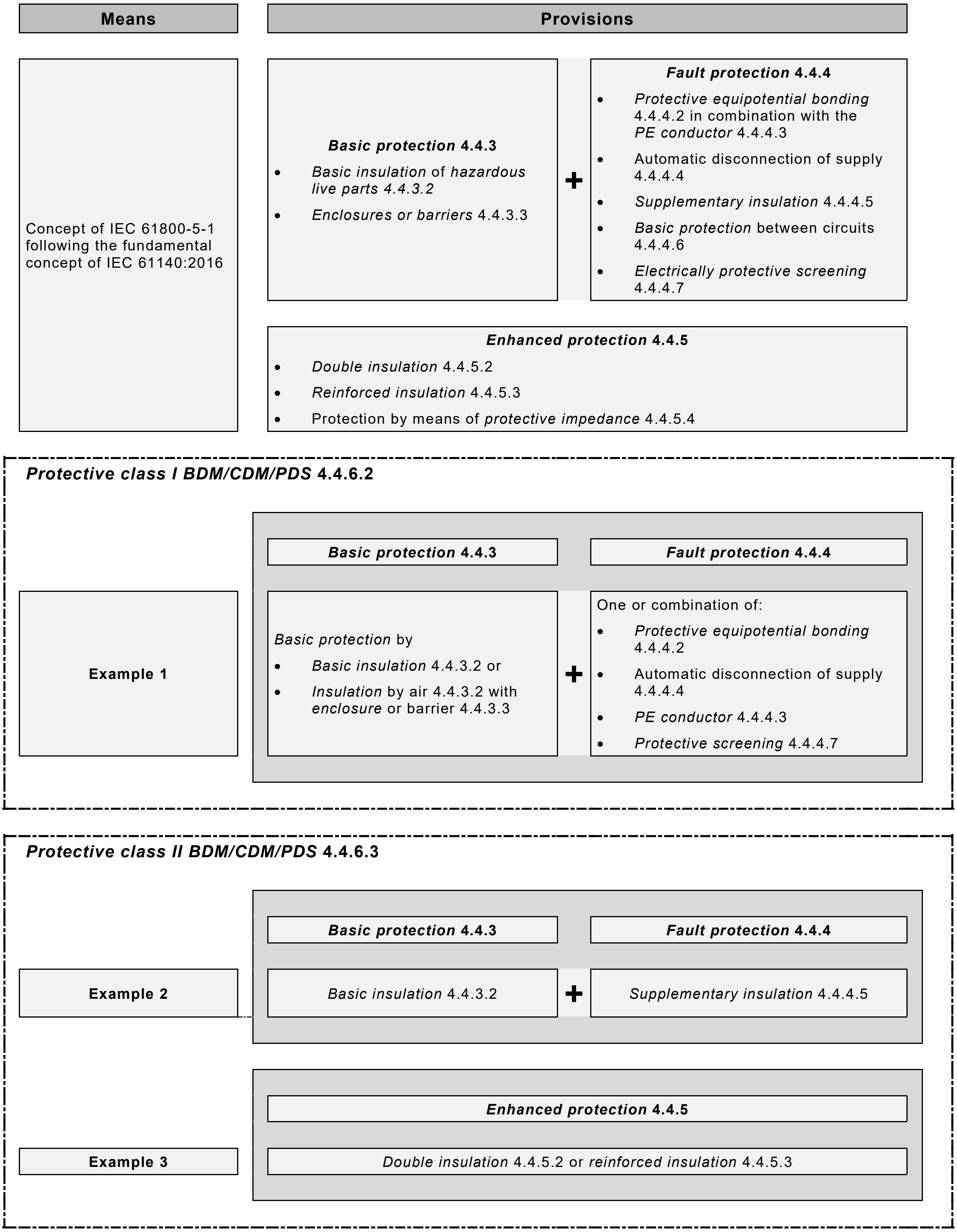


Figure A.7 – Protective measures according to 4.4.1 to 4.4.5 for protection against electric shock considering *protective class I* and *protective class II BDM/CDM/PDS*

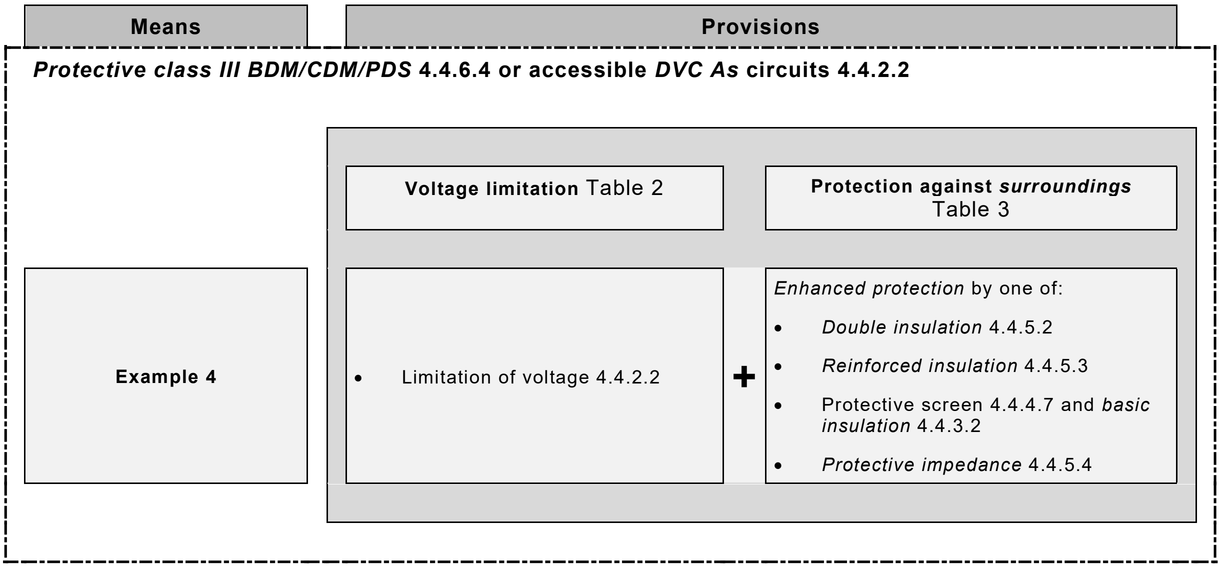


Figure A.8 – Protective measures according to 4.4.1 to 4.4.5 for protection against electric shock considering *protective class III BDM/CDM/PDS* and *DVC As* circuits

A.6.3 Examples of the use of elements of protective measures

Table A.1 provides requirements for *enclosure* or barrier openings in rows 4 and 5 (see 4.4.3.3) and also provides examples of *insulation* between *accessible part*s and *hazardous live part*s in rows 1, 2 and 3.

The required grade of *insulation* depends on

- the *DVC* of the *hazardous live parts* according *to* Table 2,
- the *insulation* requirement between *adjacent circuits* according to Table 3,
- the connection of conductive *accessible part*s to earth by *protective equipotential bonding* according to 4.4.4.2, and
- non conductive *accessible part*s.

As an alternative to *solid insulation*, a *clearance* according to 4.4.7.4, shown by L_1 and L_2 in Table A.1 may be provided.

In Table A.1, three cases are considered.

Case a) – *Accessible part*s are conductive and are connected to earth by *protective equipotential bonding*.

Without *adjacent circuit*:

- Cells 1a, 2a, 4a: *Basic protection* is required between *accessible part*s and the *hazardous live part*s. The relevant voltage is that of the *hazardous live part*s.
- Cell 5a: *Enhanced protection* is required between *accessible parts* and *hazardous live parts* of *DVC D*. The relevant voltage is that of the *hazardous live parts*.

With *adjacent circuit*:

- Cell 3a-upper row: *Basic protection* between *accessible parts* and *hazardous live parts* of circuits of *DVC B* or *C* or *D* which are separated by *basic protection* from *adjacent circuits* of *DVC B* or *DVC C* or *DVC D.* The relevant voltage is that of the *hazardous live part* with higher voltage.

- Cell 3a-lower row*: Basic protection* between *accessible parts* and *hazardous live parts* of circuits of *DVC B* or *DVC C* which have *enhanced protection* from *adjacent circuits* of *DVC C* or *DVC D.* The relevant voltage is that of the *hazardous live parts.*

Cases b) and c):

Accessible parts are non-conductive (case b) or conductive but not connected to earth by *protective equipotential bonding* (case c). The required *protection* is as follows.

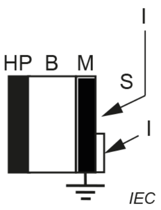
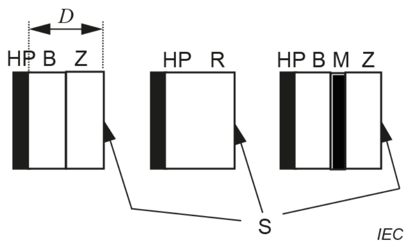
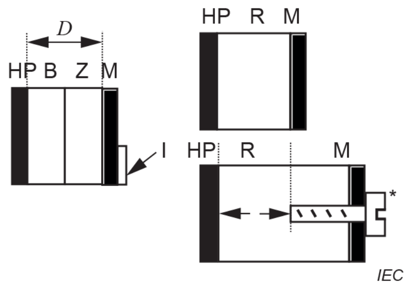
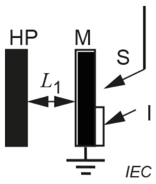
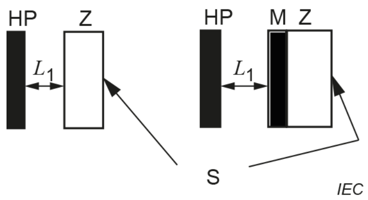
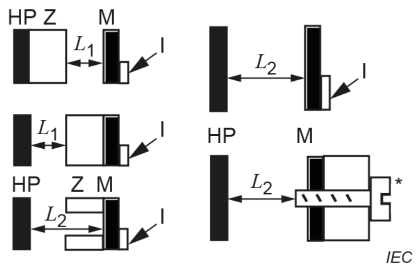
Without *adjacent circuit*: Cells 1b, 1c, 2b, 2c, 4b, 4c, 5b and 5c: *Enhanced protection* between *accessible part*s and *hazardous live parts* of *DVC C* or *DVC D*. The relevant voltage is that of the *hazardous live parts*.

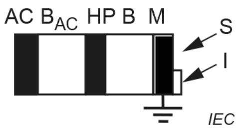
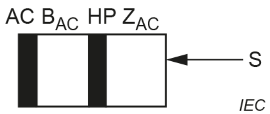
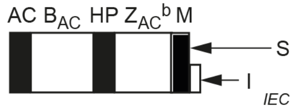
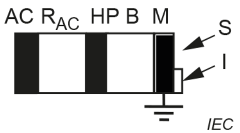
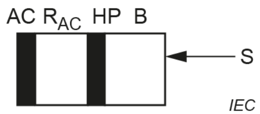
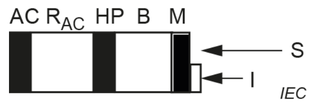
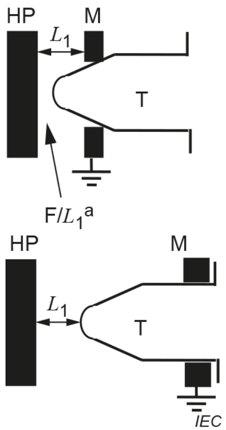
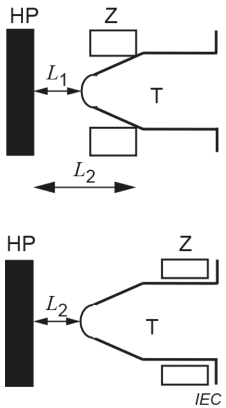
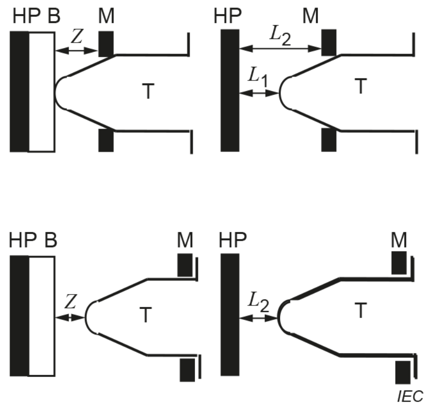
With *adjacent circuit*:

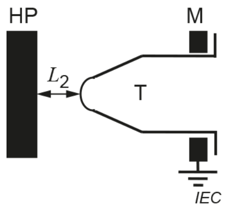
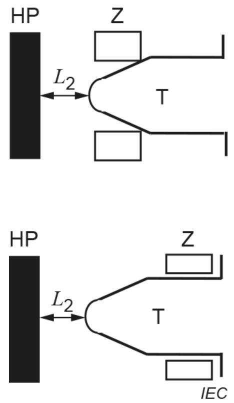
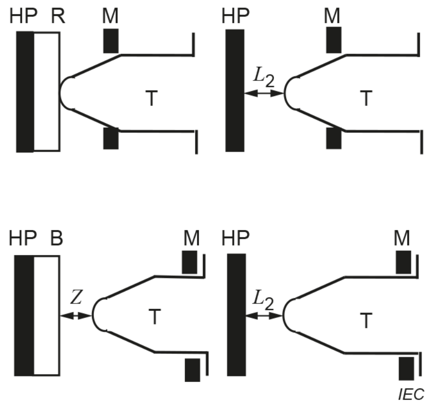
- Cells 3b-upper row, 3c-upper row: *Fault protection* between *accessible part*s and *hazardous live parts* of circuits of *DVC C* which are separated by *basic protection* from *adjacent circuits* of *DVC C.* The relevant voltage is the highest voltage of the *adjacent circuits*. This is equivalent to the requirement for *enhanced protection* between circuit AC and circuit HP and covers *basic protection* requirement between accessible surface and circuit HP.
- Cells 3b-lower row, 3c-lower row: *Basic protection* between *accessible part*s and *hazardous live parts* of circuits of *DVC C* which have *enhanced protection* from *adjacent circuits* of *DVC C or DVC D*. The relevant voltage is that of the *hazardous live parts*.

Table A.1 does not show any *insulation* requirement for *DVC As* and *DVC B.*

Table A.1 – Configurations for protection against electric shock

Type of insulation	**Insulation configuration**		
	a	**b**	**c**
	Conductive *accessible part*s connected to earth by *protective equipotential bonding*	***Accessible part*s not conductive**	***Accessible part*s conductive, but <u>NOT</u> connected to earth by *protective equipotential bonding***
1. Solid			
2. Totally or partially by air *clearance*			

Type of insulation	Insulation configuration		
	a	b	c
	Conductive *accessible part*s connected to earth by *protective equipotential bonding*	*Accessible parts* not conductive	*Accessible part*s conductive, but NOT connected to earth by *protective equipotential bonding*
3. *Insulation* for *adjacent circuits*: Circuit HP: lower voltage circuit; Circuit AC: higher voltage circuit; upper row – AC: *DVC C* only,			
lower row – AC: *DVC C* or *DVC D*			
4. Requirements for openings in *enclosures* Circuit HP: *DVC C*			

Type of insulation	**Insulation configuration**		
	a	**b**	**c**
	Conductive *accessible part*s connected to earth by *protective equipotential bonding*	***Accessible part*s not conductive**	***Accessible part*s conductive, but <u>NOT</u> connected to earth by *protective equipotential bonding***
5. Requirements for openings in *enclosures* **Circuit HP: *DVC D***			

HP *hazardous live part*	L_1 *clearance* for *basic insulation*	T test finger (test probe Figure M.2)
B *basic insulation* for circuit HP	L_2 *clearance* for *reinforced insulation*	Z *supplementary insulation* for circuit HP
B_{AC} *basic insulation* for circuit AC	M conductive part	Z_{AC} *supplementary insulation* for circuit AC
AC *adjacent circuit*	R *reinforced insulation* for circuit HP	* also applies to plastic screws
D *double insulation* for circuit HP	R_{AC} *reinforced insulation* for circuit AC	F *functional insulation* for circuit HP
I optional *insulation* less than B for purposes other than protection against electric shock	S surface of *BDM/CDM/PDS*	

NOTE 1 In column c, a plastic screw is treated like a metal screw because a user could replace it with a metal screw during the life of the *BDM/CDM/PDS*.

NOTE 2 In row 4, the insertion of the test finger is considered to represent the first fault (for information, see also IEC 60730-1, IEC 60335-1 and IEC 62368-1).

[a] *Functional insulation* is sufficient if the opening is covered during normal operating conditions. It shall not be possible to remove the *cover* without the use of a tool or key. If the opening is not covered during normal operating conditions, *basic protection* is required.

[b] When considering the *insulation* requirement Z_{AC} from the *adjacent circuit* AC in row 3a, 3b and 3c, the *insulation* requirement from circuit HP from row 1 and row 2 shall be considered as well. The protection requirement shall be the higher of the requirement for HP (*reinforced insulation* from HP) from row 1 or 2 and the requirement for AC (*supplementary insulation* from AC) in row 3.

Annex B
(informative)

Considerations for the reduction of the pollution degree

B.1 General

The objective of Annex B is to give an overview of what factors should be considered to reduce the pollution degree for electrical equipment in order to allow for a reduction of the *clearance* and *creepage distance*s. As the measures to be taken depend heavily on the nature of pollution, no comprehensive guidance can be given on how to achieve the goal of a lower pollution degree for the equipment.

B.2 Factors influencing the pollution degree

The following factors influence the pollution degree.

- Pollution
  - no pollution;
  - dry non-conductive pollution;
  - dry non-conductive pollution that can become conductive, when moist;
  - conductive pollution.

NOTE Pollution can be external or can be internally generated or present internally at the conclusion of manufacturing.

- Moisture
  - no or low moisture without condensation;
  - temporary condensation;
  - permanent moisture;
  - rain or snow.

B.3 Reduction of influencing factors

Following are some measures that may be applied to reduce the influencing factors. The described measures to meet the requirements are only illustrative. There may be other possibilities.

- coating or potting (see 4.4.7.6);
- IP5X (dust test according to IEC 60529);
- IPX4 to IPX8 depending on the environment.

When hermetically sealing an electrical equipment, it should be ensured that the moisture level will be at the required low level when resealing the equipment after opening the *enclosure* (e.g. for service).

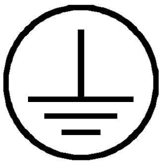
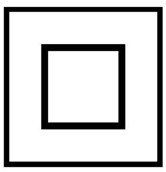
Annex C
(informative)

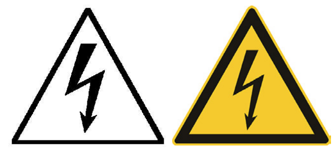
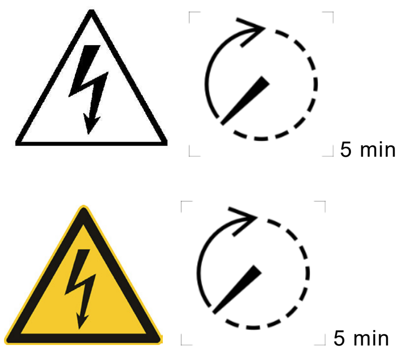
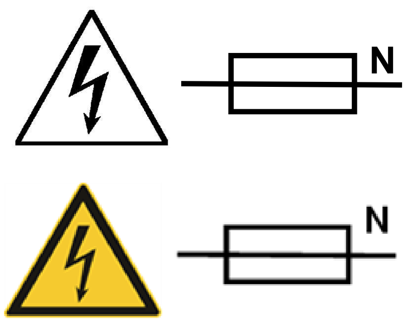
Symbols referred

C.1 Symbols used

An overview of the symbols used in this document is given in Table C.1.

Table C.1 – Symbols used

Symbol	Standard reference	Description	Subclauses
	IEC 60417-5019:2006-08	Protective earth; protective ground (*PE conductor* terminal) *Protective class I*	4.4.4.2.1, 4.4.4.3.2, 6.3.9.2.2
	IEC 60417-5017:2006-08	*PE conductor* terminal	4.4.4.3.2, 6.3.9.2.2
	IEC 60417-5018:2011-07	Functional earthing terminal	4.4.6.3 6.3.9.2.3
  	ISO 7010-W001:2011-05 or ISO 7000-0434a:2004-01 or ISO 7000-0434b:2004-01	Warning, refer to documentation	4.4.4.3.3, 4.4.8, 4.8, 4.11.11.3, 6.3.7.5, 6.3.9.4, 6.5.7, P.5
	IEC 60417-5172:2003-02	*Protective class II (double insulation) BDM/CDM/PDS*	4.4.6.3 6.3.9.2.3
	IEC 60417-5180:2003-02	*Protective class III BDM/CDM/PDS*	4.4.6.4, 6.3.9.2.4

Symbol	Standard reference	Description	Subclauses
	IEC 60417-6042:2010-11 or ISO 7010-W012:2011-05	Warning, risk of electric shock	4.4.9, 4.8, 6.5.7
	IEC 60417-5041:2002-10 or ISO 7010-W017:2011-05	Caution, hot surface	4.6.5.3, 6.4.4
	IEC 60417-6042:2010-11 or ISO 7010-W012:2011-05 and IEC 60417-5416:2015-04 and indicating the time	Warning, risk of electric shock Remaining time display; processing (Capacitor discharge time)	4.4.9, 6.5.2
	IEC 60417-6042:2010-11 or ISO 7010-W012:2011-05 and IEC 60417-5016:2002-10 and an indication that the fuse is in the neutral N	Caution, Double pole/neutral fusing	4.3.4, 6.2
	ISO 7010-M002:2011-05	Refer to instruction manual/booklet (Refer to instruction, Installation, user's and/or maintenance manuals)	6.1, 6.1.3

C.2 Determination of contrast

Where the colour *system* of ISO 7010 for safety and warning signs is not used, the relative contrast can be calculated using the light reflectance value (LRV) of each of the background and the text/symbol colour using the formula of ISO 21542:2011[4]:

$$C = 100 \times \frac{LRV_1 - LRV_2}{LRV_1}$$

where

LRV_1 is the LRV of the lighter colour;

LRV_2 is the LRV of the darker colour.

NOTE 1 The above equation is the Weber contrast equation.

An acceptable visual contrast is achieved, if

- the lighter colour has an LRV of at least 40, and
- the relative contrast is minimum 80 %.

NOTE 2 The lighter colour LRV of 40 is taken as an approximation of RAL 1003[5] (signal yellow) as required by ISO 3864-4:2011, which has an LRV of approximately 48.

NOTE 3 The relative contrast requirement is taken from the recommendation of ISO 3864-4:2011, Clause D.2.

EXAMPLE 1

White (RAL 9010, pure white): LRV_1 = 84

Black (RAL 9004, signal black): LRV_2 = 2

Relative contrast = ((84 – 2) / 84) = 98 %

EXAMPLE 2

Yellow (RAL 1003, signal yellow): LRV_1 = 48

Black (RAL 9004, signal black): LRV_2 = 2

Relative contrast = ((48 – 2) / 48) = 96 %

EXAMPLE 3

Blue (RAL 5012, signal blue): LRV_1 = 21

White (RAL 9010, pure white): LRV_1 = 84

Relative contrast = ((84 – 21) / 84) = 75 %

NOTE 4 Any other *system* than RAL can be suitable as well, provided that the light reflective values are measured in the same *system*. Also within the RAL *system* the light reflective values can have slighly different values depending on the source used.

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[4] This publication has been withdrawn.

[5] RAL is an example of a colour order *system* available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of this product.

Annex D
(normative)

Evaluation of *clearance* and *creepage distance*s

D.1 Measurement

Clearance and *creepage distance*s shall be evaluated as illustrated in the examples contained in examples Figure D.1 to Figure D.15.

For paths consisting of parts with different pollution degrees, as for example when including a cemented joint that provides protection type 1 (IEC 60664-3) in a pollution degree 2 environment, the *clearance* and *creepage distance*s are determined according to Table 8 and Table 10, using the following rules.

- In general, a *creepage distance* may be split in several portions of different materials and/or have different pollution degrees if one of the *creepage distance*s is dimensioned to withstand the total voltage or if the total distance is dimensioned according to the material having the lowest CTI and the highest pollution degree.
- For *creepage distance*s for *functional insulation* on PWB and *components* assembled on PWB, designed for pollution degree 1 and 2, the sum of the determining voltages of each part of the path shall not be less than the determining voltage of the circuits involved. The distances for each portion of the *creepage distance* under consideration shall comply with the minimum distances according to Table D.1.

D.2 Relationship of measurement to pollution degree

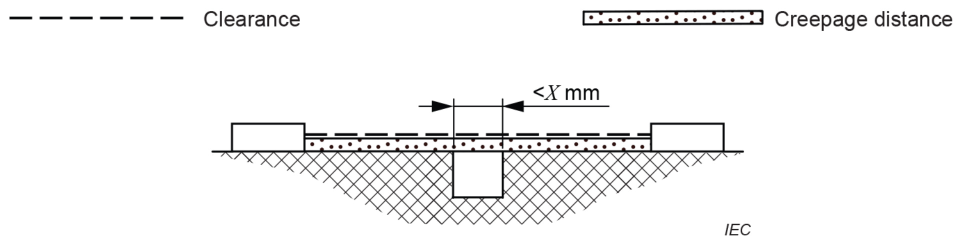
The "X" values are a function of pollution degree and shall be as specified in Table D.1. If the associated required *clearance* is less than 3 mm, the X value is one third of the *clearance*.

Table D.1 – Width of grooves by pollution degree

Pollution degree	X value mm
1	0,25
2	1,0
3	1,5

D.3 Examples

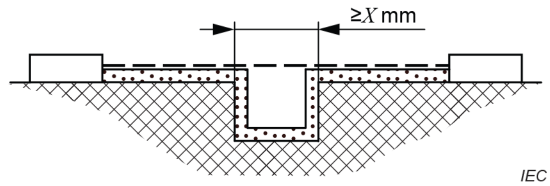
In the examples shown in Figure D.1 to Figure D.14 below, *clearance* and *creepage distance*s are denoted as follows:



Condition: The path under consideration includes a parallel, diverging or converging-sided groove of any depth with a width less than X mm.

Rule: *Creepage distance* and *clearance* are measured directly across the groove as shown.

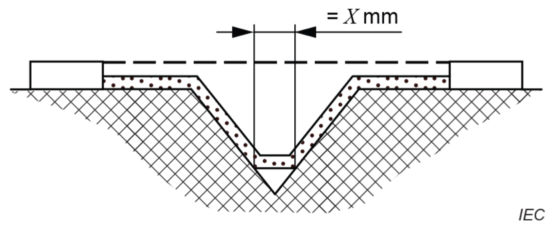
Figure D.1 – Example of measurements including a groove



Condition: Path under consideration includes a parallel or diverging-sided groove of any depth with a width equal to or more than X mm.

Rule: *Clearance* is the "line of sight" distance. *Creepage distance* path follows the contour of the groove.

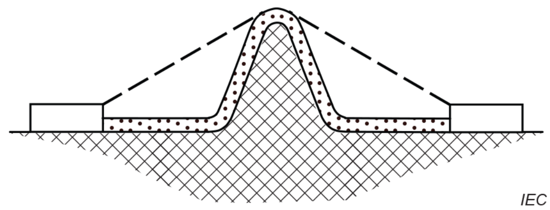
Figure D.2 – Example of measurements including a groove



Condition: Path under consideration includes a V-shaped groove with a width greater than X mm.

Rule: *Clearance* is the "line of sight" distance. *Creepage distance* path follows the contour of the groove but "short-circuits" the bottom of the groove by X mm link.

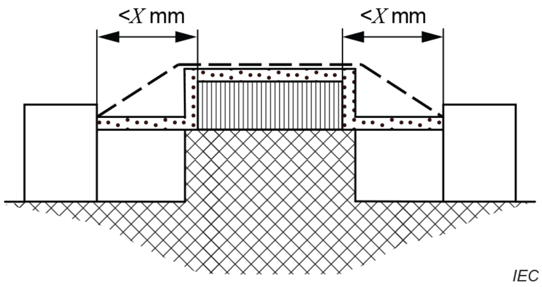
Figure D.3 – Example of measurements including a groove



Condition: Path under consideration includes a rib.

Rule: *Clearance* is the shortest air path over the top of the rib. *Creepage distance* path follows the contour of the rib.

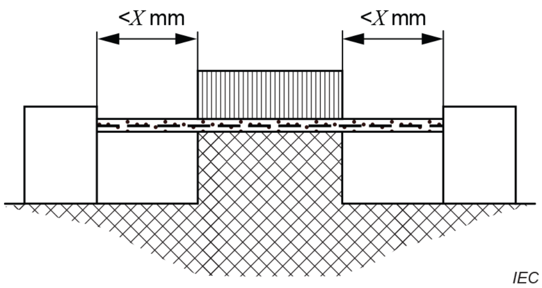
Figure D.4 – Example of measurements including a rib



Condition: Path under consideration includes a cemented joint that provide protection of type 2 (see 4.4.7.8.4.3) with grooves less than X mm wide on each side.

Rule: *Clearance* is the shortest air path over the top of the joint. *Creepage distance* is measured directly across the grooves and follows the contour of the joint.

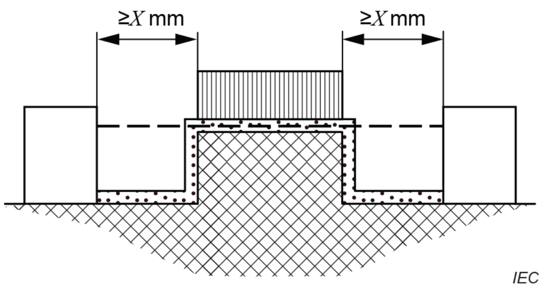
Figure D.5 – Example of measurements providing protection of type 2



Condition: Path under consideration includes an uncemented joint or a cemented joint that provide protection of type 1 (see 4.4.7.8.4.3) with grooves less than X mm wide on each side.

Rule: *Clearance* and *creepage distance* path is the "line of sight" distance shown.

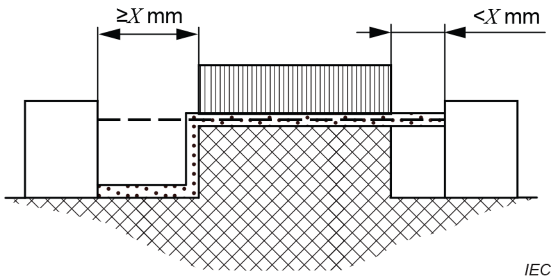
Figure D.6 – Example of measurements providing protection of type 1



Condition: Path under consideration includes an uncemented joint or a cemented joint that provide protection of type 1 (see 4.4.7.8.4.3) with grooves equal to or more than X mm wide on each side.

Rule: *Clearance* is the "line of sight" distance. *Creepage distance* path follows the contour of the grooves.

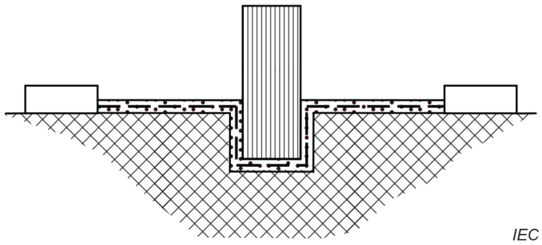
Figure D.7 – Example of measurements providing protection of type 1



Condition: Path under consideration includes an uncemented joint or a cemented joint that provide protection of type 1 (see 4.4.7.8.4.3) with a groove on one side less than X mm wide and the groove on the other side equal to or more than X mm wide.

Rule: *Clearance* and *creepage distance* paths are as shown.

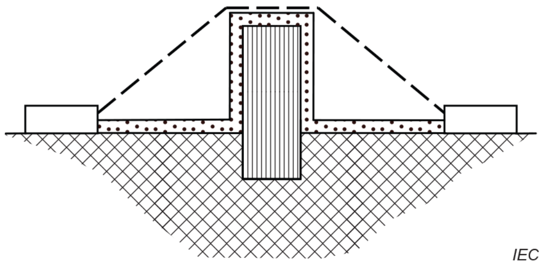
Figure D.8 – Example of measurements providing protection of type 1



Condition: Path under consideration includes an uncemented barrier or a cemented joint that provide protection of type 1 (see 4.4.7.8.4.3) when path under the barrier is less than the path over the barrier.

Rule: *Clearance* and *creepage distance* paths follow the contour under the barrier.

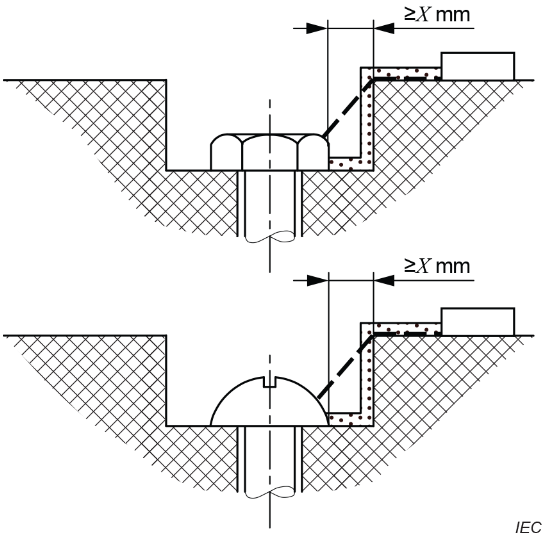
Figure D.9 – Example of measurements including a barrier (cemented joint)



Condition: Path under consideration includes an uncemented or a cemented barrier when path over the barrier is less than the path under the barrier.

Rule: *Clearance* is the shortest air path over the top of the barrier. *Creepage distance* path follows the contour of the barrier.

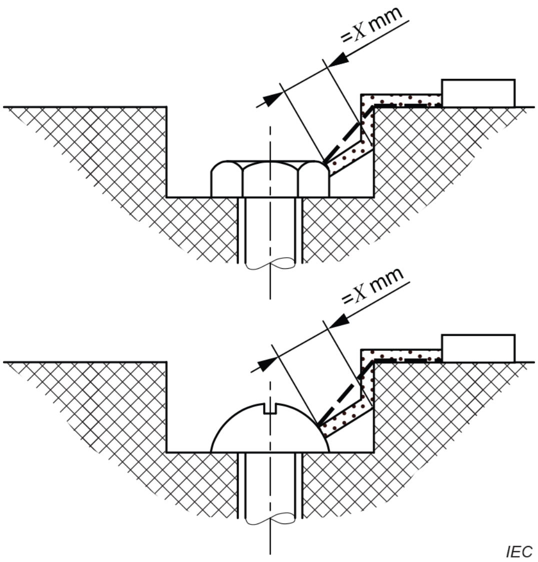
Figure D.10 – Example of measurements including a barrier



Condition: Path under consideration includes a gap between head of screw and wall of recess which is equal to or more than X mm wide.

Rule: *Clearance* is the shortest air path through the gap and over the top surface. *Creepage distance* path follows the contour of the surfaces.

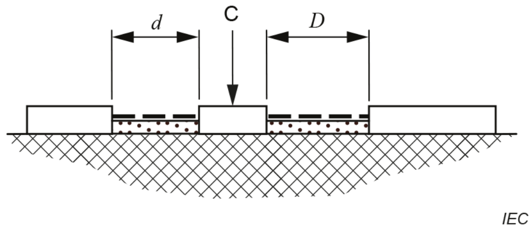
Figure D.11 – Example of measurements including a gap



Condition: Path under consideration includes a gap between head of screw and wall of recess which is less than X mm wide.

Rule: *Clearance* is the shortest air path through the gap and over the top surface. *Creepage distance* path follows the contour of the surfaces but "short-circuit" the bottom of the recess by X mm link.

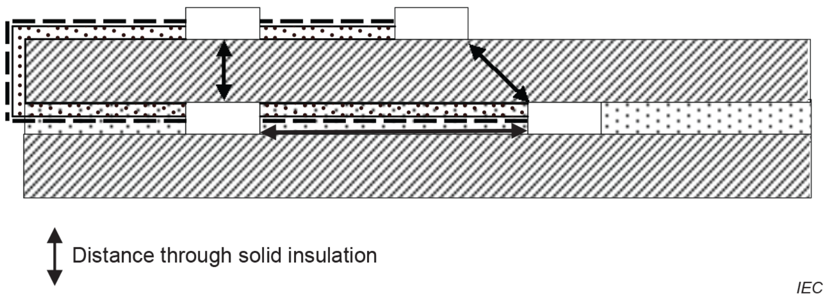
Figure D.12 – Example of measurements including a gap



Condition: Path under consideration includes a floating part of conductive material C.

Rule: *Clearance* and *creepage distance* paths are the sum of d plus D.

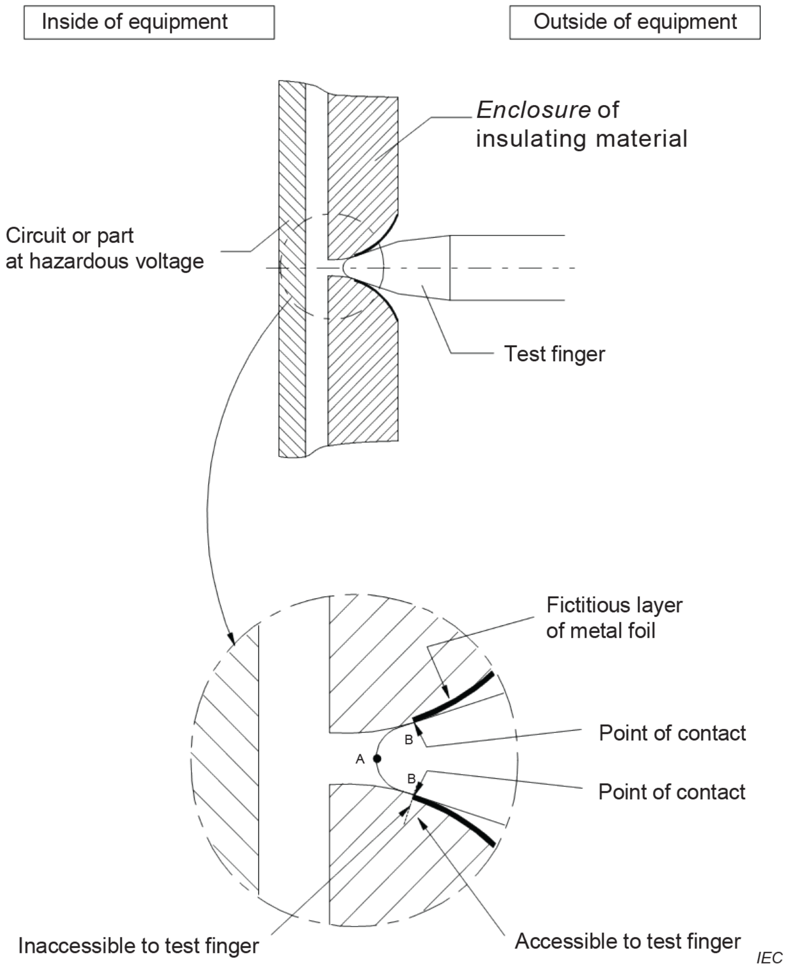
Figure D.13 – Example of measurements including an floating conductive part



Condition: Path under consideration includes inner layer of PWB.

Rule: For the inner layer(s), the distance between adjacent tracks on the same layer is treated either as *creepage distance* for pollution degree 1 and *clearance* as in air (see 4.4.7.8.4.2 a)) or *solid insulation* (see 4.4.7.8.4.2).

Figure D.14 – Example of measurements in inner layer of PWB



Point A is used for determining the air gap to a part inside the *enclosure*.

Point B is used for measurements of *clearance* and *creepage distance* from the outside of an *enclosure* of insulating material to a part inside the *enclosure*.

Figure D.15 – Example of measurements in an *enclosure* of insulating material

Annex E
(normative)

Altitude correction for *clearance*s

E.1 Correction factor for *clearance*s at altitudes above 2 000 m

Dimensioning of *clearance*s at altitudes between 2 000 m and 20 000 m according to 4.4.7.4.3 in combination with the correction factor from Table E.1.

Table E.1 – Correction factor for *clearance*s at altitudes between 2 000 m and 20 000 m

Altitude m	**Normal barometric pressure** kPa	**Multiplication factor for *clearance*s**
2 000	80,0	1,00
3 000	70,0	1,14
4 000	62,0	1,29
5 000	54,0	1,48
6 000	47,0	1,70
7 000	41,0	1,95
8 000	35,5	2,25
9 000	30,5	2,62
10 000	26,5	3,02
15 000	12,0	6,67
20 000	5,5	14,50
Source: IEC 60664-1:2020, Table A.2. Linear interpolation is permitted. See IEC 60664-1:2020, 5.2.3.4.		

E.2 Test voltages for verifying *clearance*s at different altitudes

Since the withstand voltage of air depends on the air pressure and thus on the altitude of the test laboratory above sea level, the test voltage (see 5.2.3.2 and Table 28) shall be corrected according to Table E.2.

Table E.2 – Test voltages for verifying *clearance*s at different altitudes

Impulse withstand voltage in kV				
Altitude of the testing laboratory				
2 000 m [a]	**1 000 m**	**500 m**	**200 m**	**0 m**
0,33	0,36	0,37	0,38	0,39
0,50	0,54	0,56	0,57	0,58
0,80	0,87	0,90	0,92	0,93
1,50	1,6	1,7	1,7	1,8
2,50	2,8	2,9	3,0	3,1
4,00	4,4	4,7	4,8	4,9
6,00	6,7	7,0	7,2	7,4
8,00	8,9	9,4	9,6	9,8
12,00	13	14	15	15
20,00	22	24	24	25
40,00	45	47	49	50
60,00	67	71	73	75
75,00	84	89	92	94
80,00	90	95	98	100
95,00	106	112	116	119
100,00	112	118	122	125
125,00	140	148	153	157
145,00	163	172	178	182

NOTE 1 Explanations concerning the influencing factors (air pressure, altitude, temperature, humidity) with respect to electric strength of *clearance*s are given in IEC 60664-1:2020, 6.2.2.1.4.

NOTE 2 When testing *clearance*s, associated *solid insulation* will be subjected to the test voltage. As the *impulse withstand voltage* test voltage is increased with respect to the rated *impulse withstand voltage*, *solid insulation* will be designed accordingly. This results in an increased impulse withstand capability of the *solid insulation*.

NOTE 3 Values given above have been rounded from the calculation in IEC 60664-1:2020, 6.2.2.1.4.

[a] Values from Table 6 and Table 7.

The voltage values of Table E.2 apply for the verification of clearances only.

Annex F
(normative)

Clearance and *creepage distance* determination for frequencies greater than 30 kHz

F.1 General influence of the frequency on the withstand characteristics

The *insulation* requirement for *clearance*, *creepage distance* and *solid insulation* as mentioned in 4.4.7 are given for frequencies up to and including 30 kHz. For higher frequencies, a reduction of the withstand capability of any type of *insulation* needs to be expected and taken into account for dimensioning.

For frequencies greater than 30 kHz and up to 10 MHz, IEC 60664-4:2005 shall be applied together with IEC 60664-1:2020, for the design of *clearance* and *creepage distance*s as well as *solid insulation*.

Annex F provides detailed information for the design of *clearance*, *creepage distance* and *solid insulation* based on the requirement from IEC 60664-4:2005.

The following situation needs to be considered for the design:

- *clearance* for inhomogenous fields (see F.2.2);
- *clearance* for approximately homogenous fields (see F.2.3);
- *creepage distance* (see Clause F.3);
- *solid insulation* (see Clause F.4).

The result of the investigation for frequencies above 30 kHz shall be compared to the investigation in 4.4.7 and the greater value of the two investigations shall be chosen.

F.2 *Clearance*

F.2.1 General

The withstand voltage capability within the scope of IEC 60664-4:2005 is influenced by the frequency for periodic voltages. For transient overvoltages, dimensioning according to 4.4.7.4 shall be used.

For frequencies exceeding 30 kHz within the scope of IEC 60664-4:2005, the withstand voltage capability of *clearance*s with homogenous and approximately homogenous field distribution can be reduced by up to 25 %. See Figure F.1.

The requirement for *clearance* depends on the field distribution of the *insulation* under investigation. F.2.2 gives the requirement for *clearance* for inhomogenous fields and F.2.3 provide design criteria for *clearance* for approximately homogenous fields.

For frequencies exceeding 30 kHz, an approximately homogeneous field is considered to exist when the radius of curvature r of the conductive parts is equal or greater than 20 % of the *clearance*. The necessary radius of curvature can only be specified at the end of the dimensioning procedure.

The result of the investigation of *clearance* for frequencies above 30 kHz shall be compared to the investigation in 4.4.7.4 and the greater value of the two investigations shall be chosen.

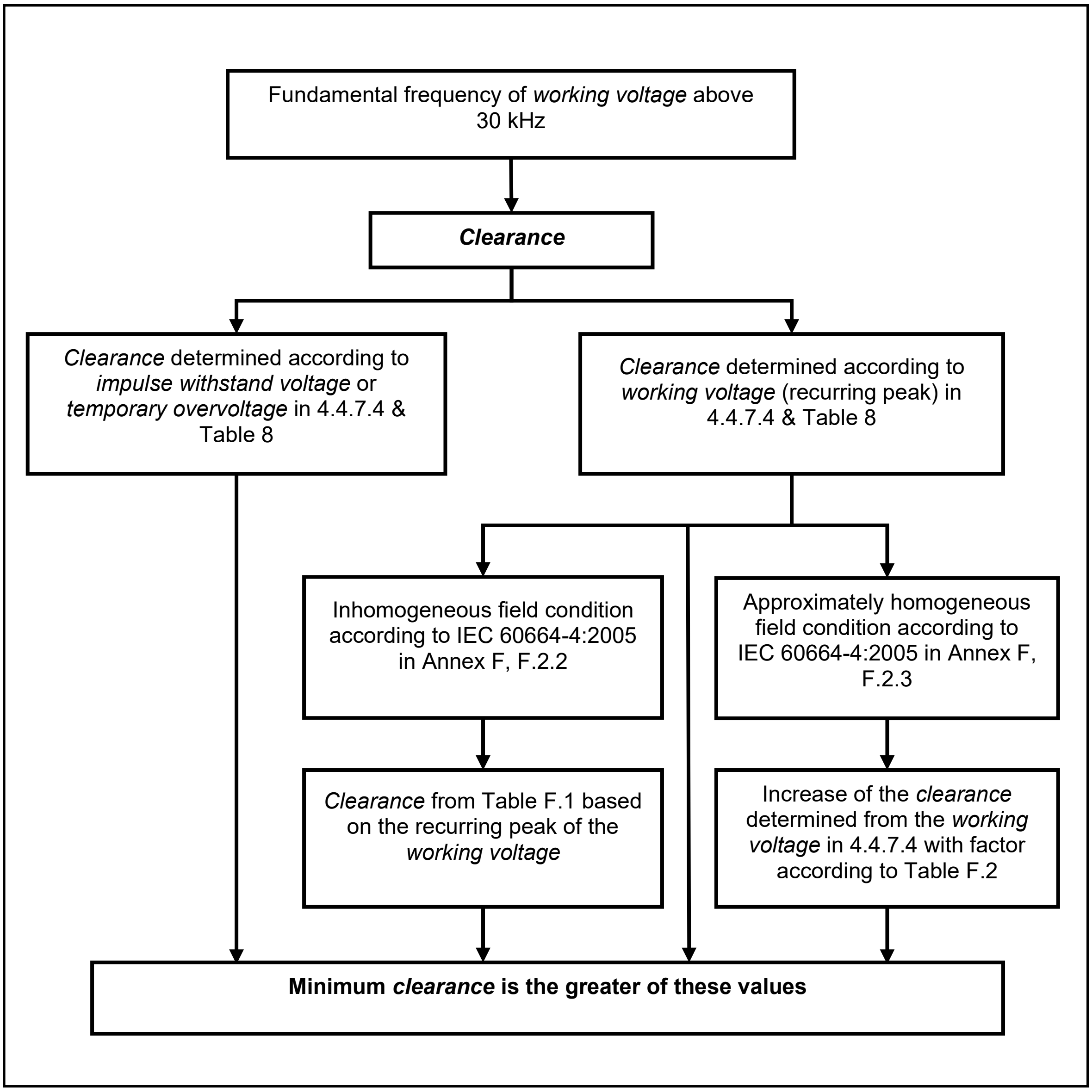


Figure F.1 – Diagram for dimensioning of *clearance*s above 30 kHz

F.2.2 *Clearance* for inhomogenous fields

For frequencies exceeding 30 kHz, an inhomogeneous field is considered to exist when the radius of curvature of the conductive parts is less than 20 % of the *clearance*. For inhomogeneous field distribution, the reduction of the withstand voltage capability of *clearance*s can be much higher.

Dimensioning for inhomogeneous field distribution is done for the required withstand voltage of the *clearance* according to the values in Table F.1. No withstand voltage test other than the requirement in 4.4.7 is required.

Table F.1 – Minimum values of *clearance*s in air at atmospheric pressure for inhomogeneous field conditions

Peak voltage [a] kV	***Clearance*** mm
≤ 0,6 [b]	0,065
0,8	0,18
1,0	0,5
1,2	1,4
1,4	2,35
1,6	4,0
1,8	6,7
2,0	11,0

SOURCE: IEC 60664-4:2005, Table 1.

[a] For voltages between the values stated in this table, interpolation is permitted.

[b] No data is available for peak voltages less than 0,6 kV.

The dimensioning for inhomogeneous field and high-voltage stress (> 1 kV condition) leads to impractical distances. It is therefore preferable to choose a design improving the field distribution (approximately homogeneous field distribution).

F.2.3 *Clearance* for approximately homogenous fields

For *clearance* with approximately homogenous fields conditions, the *clearance* found in Table 8, where the *clearance* is determined on the *working voltage* (recurring peak) (column 3), is increased by a multiplication factor depending on the fundamental frequency. The multiplication factors are indicated in Table F.2.

Table F.2 – Multiplication factors for *clearance*s in air at atmospheric pressure for approximately homogeneous field conditions

Fundamental frequency kHz	**Multiplication factor**
$30 < f_{\text{fundamental}} \leq 500$	1,05
$500 < f_{\text{fundamental}} \leq 1\,000$	1,10
$1\,000 < f_{\text{fundamental}} \leq 2\,000$	1,20
$2\,000 < f_{\text{fundamental}} \leq 3\,000$	1,25

NOTE 1 The multiplication factors are determined based on calculations as per IEC 60664-4:2005, 4.3.3. More precise calculation can be determined using the formula in IEC 60664-4:2005, 4.3.3.

NOTE 2 Circuits where the *clearance* is designed based on the *impulse withstand voltage* (Table 8, column 1), will normally not be affected by these considerations.

The dimensioned *clearance*, for approximately homogenous field conditions, is applicable for frequencies above the critical frequency calculated by means of the following formula taking into account the new distance from Table F.2:

$$f_{\text{crit}} \approx \frac{0{,}2}{d}\left(\frac{\text{MHz}}{\text{mm}}\right)$$

F.3 *Creepage distance*

For frequencies of the voltage greater than 30 kHz, in addition to tracking, thermal effects need to be taken into account with respect to the withstand capability of *creepage distance*s. Dimensioning is performed both for the required RMS withstand voltage of the *creepage distance* according to the values in Table 10 and for the required peak withstand voltage according to the values in Table F.3. This peak withstand voltage is the highest value of any periodic peak of the voltage across the *creepage distance*. The greater of the distances is applicable. The dimensioning according to Table F.3 is applicable for all insulating materials which can deteriorate due to thermal effects. This includes typical base materials for printed wiring boards (PWB) made from epoxy resin. For materials which cannot deteriorate due to thermal effects and where no tracking needs to be expected, dimensioning according to the *clearance* requirements, as described in 4.4.7.5, is sufficient. See Figure F.2.

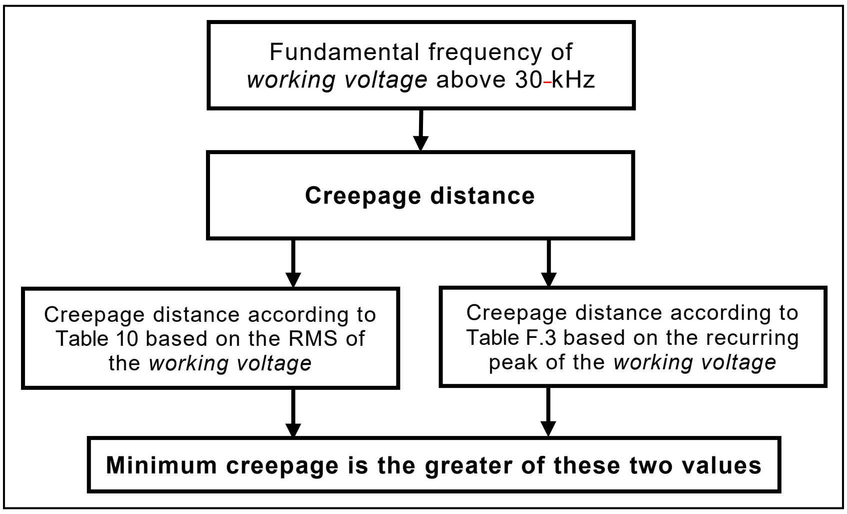


Figure F.2 – Diagram for dimensioning of *creepage distance*s above 30 kHz

Table F.3 – Minimum values of *creepage distance*s for different frequency ranges

Peak voltage kV	*Creepage distance* [a b] mm						
	30 kHz < f ≤ 100 kHz	**f ≤ 0,2 MHz**	**f ≤ 0,4 MHz**	**f ≤ 0,7 MHz**	**f ≤ 1 MHz**	**f ≤ 2 MHz**	**f ≤ 3 MHz**
0,1	0,0167	--	--	--	--	--	0,3
0,2	0,042	--	--	--	--	0,15	2,8
0,3	0,083	0,09	0,09	0,09	0,09	0,8	20
0,4	0,125	0,13	0,15	0,19	0,35	4,5	--
0,5	0,183	0,19	0,25	0,4	1,5	20	--
0,6	0,267	0,27	0,4	0,85	5	--	--
0,7	0,358	0,38	0,68	1,9	20	--	--
0,8	0,45	0,55	1,1	3,8	--	--	--
0,9	0,525	0,82	1,9	8,7	--	--	--
1	0,6	1,15	3	18	--	--	--
1,1	0,683	1,7	5	--	--	--	--
1,2	0,85	2,4	8,2	--	--	--	--
1,3	1,2	3,5	--	--	--	--	--
1,4	1,65	5	--	--	--	--	--
1,5	2,3	7,3	--	--	--	--	--
1,6	3,15	--	--	--	--	--	--
1,7	4,4	--	--	--	--	--	--
1,8	6,1	--	--	--	--	--	--

SOURCE: IEC 60664-4:2005, Table 2.

[a] The values for the *creepage distance*s in the table apply for pollution degree 1. For pollution degree 2, a multiplication factor of 1,2 and for pollution degree 3 a multiplication factor 1,4 shall be used.

[b] Interpolation between columns is permitted.

F.4 *Solid insulation*

F.4.1 General

Due to increased heating effects and accelerated deterioration in *solid insulation,* further consideration is needed when using *solid insulation* for *insulation* barriers affected by frequencies above 30 kHz.

F.4.2 Approximately uniform field distribution without air gaps or voids

For *solid insulation* where uniform field distribution is present and no air gaps or voids are present in the *solid insulation*, the maximum field distribution shall be calculated as follows.

- For thick layers of *solid insulation* of d_1 ≥ 0,75 mm, the peak value of the field strength E needs to be equal or less than 2 kV/mm.
- For thin layers of *solid insulation* of d_2 ≤ 30 μm, the peak value of the field strength needs to be equal or less than 10 kV/mm.

For $d_1 > d > d_2$, Formula (F.1) is used for interpolation for a certain thickness d (see also Figure F.3

$$E = \left(\frac{0{,}25}{d} + 1{,}667\right)\left(\frac{\text{kV}}{\text{mm}}\right) \qquad (\text{F.1})$$

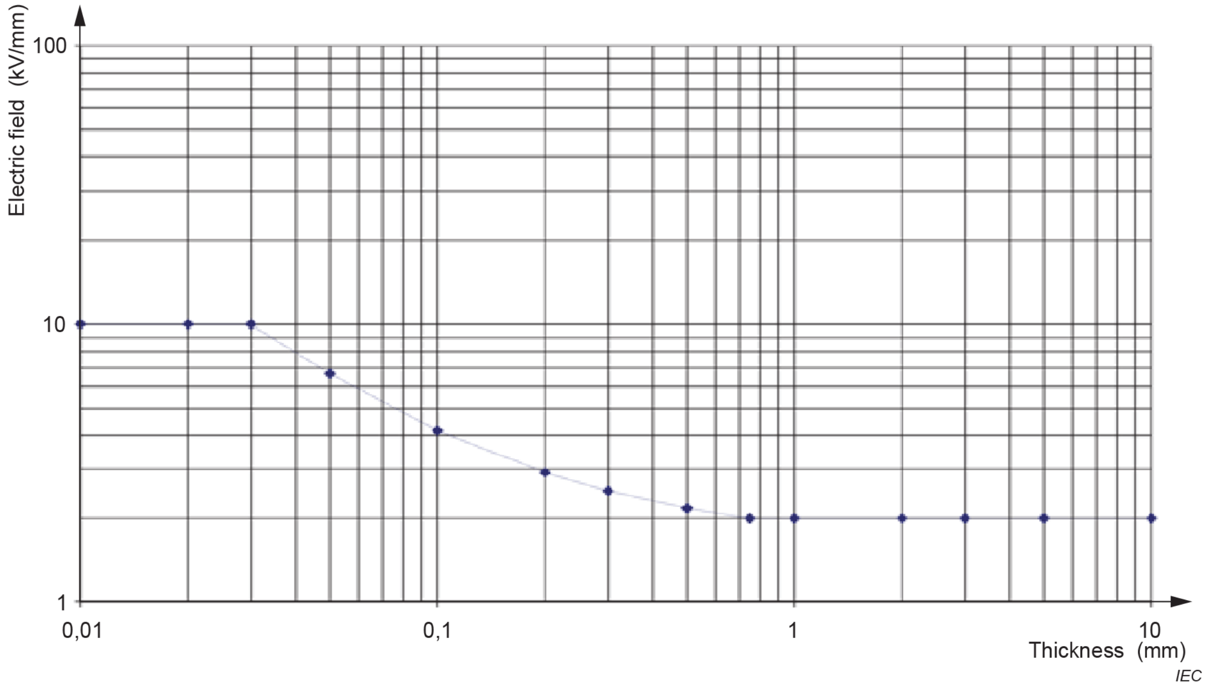


Figure F.3 – Permissible field strength for dimensioning of *solid insulation* according to Formula (F.1)

F.4.3 Other cases

The evaluation according to 4.4.7.8 for *solid insulation* shall be performed, where

- uniform field distribution is not present,
- air gaps or voids are to be expected, or
- the field strength is above the calculation in F.4.2.

If possible, the partial discharge test described in 5.2.3.5 should be performed with the frequency which is present over the *insulation* under evaluation when evaluation is made according to Annex F. At the time of writing, such test equipment is not commonly available, and this document allows test to be conducted at 50 Hz or 60 Hz.

Annex G
(informative)

Cross-sections of round conductors

Standard values of cross-section of round copper conductors are shown in Table G.1, which also gives the approximate relationship between ISO metric and AWG/MCM sizes.

Table G.1 – Standard cross-sections of round conductors

	AWG/kcmil	
ISO cross-section mm^2	**Size**	**Equivalent cross-section** mm^2
0,2	24	0,205
–	22	0,324
0,5	20	0,519
0,75	18	0,82
1,0	–	–
1,5	16	1,3
2,5	14	2,1
4,0	12	3,3
6,0	10	5,3
10	8	8,4
16	6	13,3
25	4	21,2
35	2	33,6
50	0	53,5
70	00	67,4
95	000	85,0
–	0000	107,2
120	250 kcmil	127
150	300 kcmil	152
185	350 kcmil	177
240	500 kcmil	253
300	600 kcmil	304
–	700 kcmil	355
–	750 kcmil	380
400	800 kcmil	405
–	900 kcmil	456
500	1 000 kcmil	506
630	1 250 kcmil	633
–	1 500 kcmil	760
800	–	–
–	1 750 kcmil	887
1 000	2 000 kcmil	1 013
NOTE The dash, when it appears, counts as a size when considering connecting capacity (see 4.11.11.2).		

Annex H
(informative)

Guidelines for RCD compatibility

H.1 Selection of RCD type

Depending on the nature of the power supply, its *installation* and the type of RCD (type A, type AC, type B or type F – see IEC 60755), *PDS* and RCD can be compatible or incompatible (see 4.4.8). If circuits which can cause current with a DC component to flow in the *PE conductor* during normal operating conditions or during *single-fault conditions* are not separated from the surroundings by *double insulation* or *reinforced insulation*, it is considered that the *PDS* itself can cause smooth DC current and is therefore incompatible with RCDs of type AC, type A and type F.

The flow chart in Figure H.1 will help with the selection of the RCD type when using adownstream of the RCD.

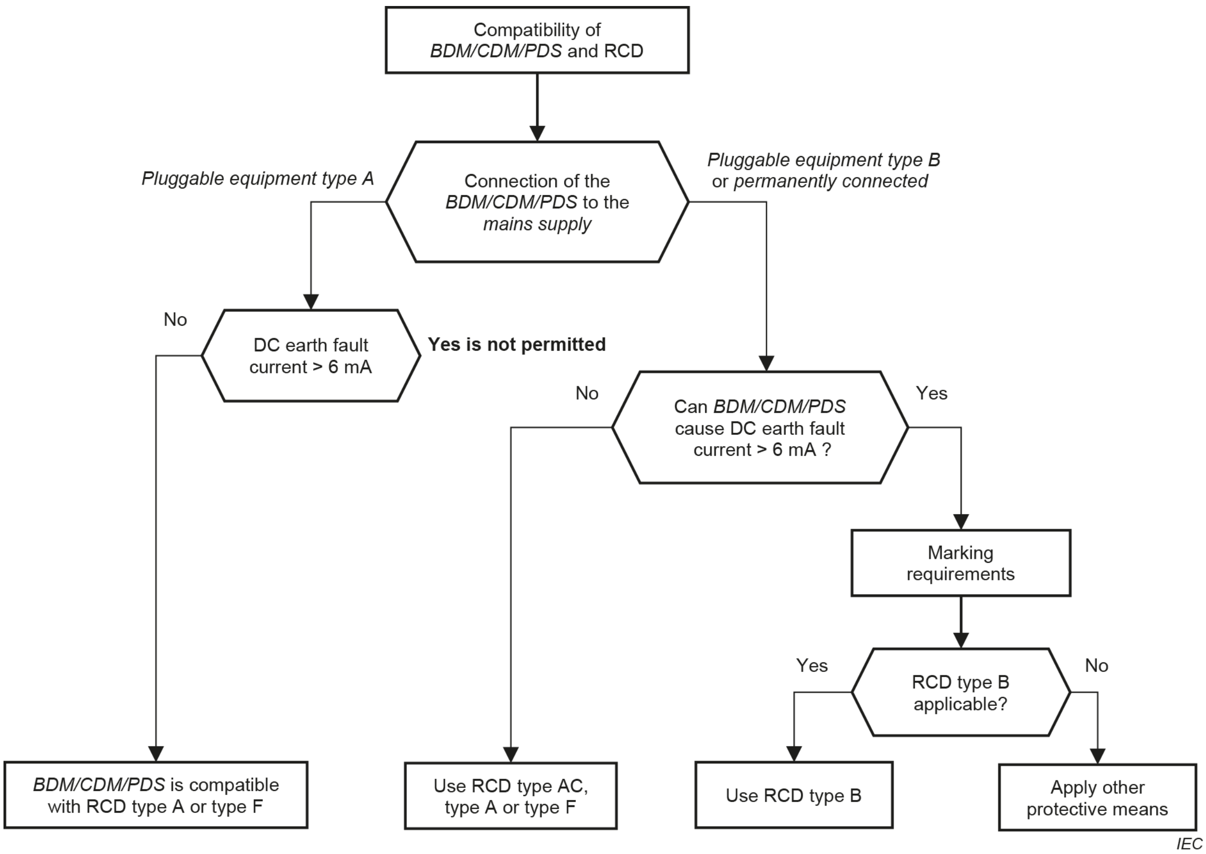


Figure H.1 – Flow chart leading to selection of the RCD type upstream of a *PDS*

RCDs suitable to be triggered by different waveforms of residual current are marked with the following symbols in Figure H.2, as defined in IEC 60755.

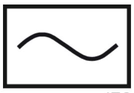
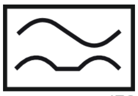
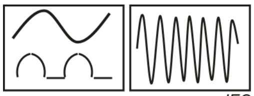
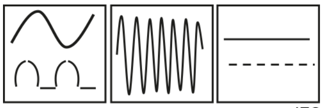
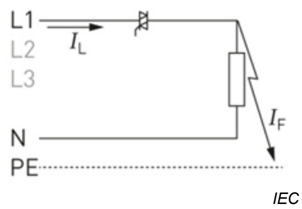
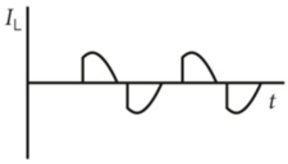
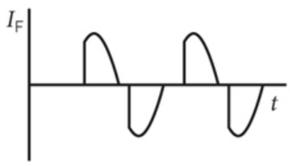
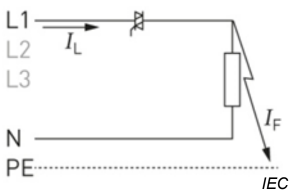
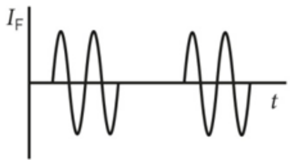
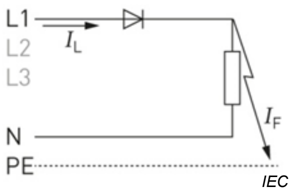
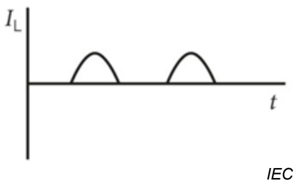
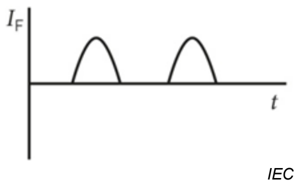
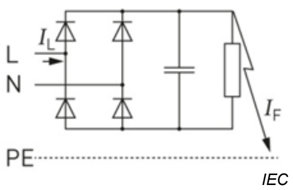
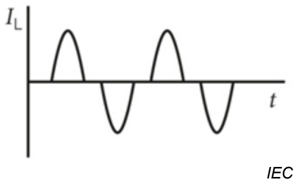
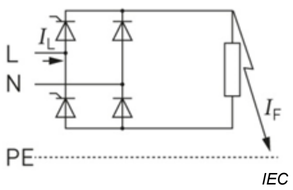
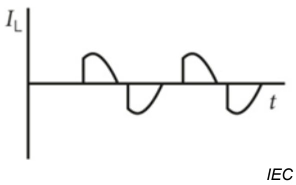
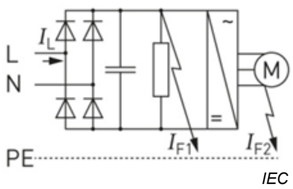
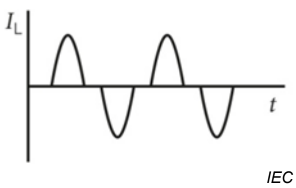
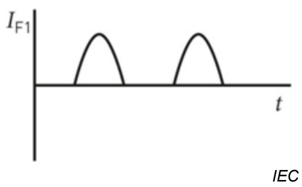
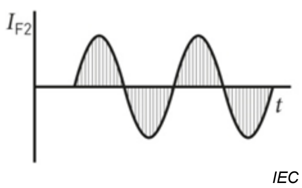
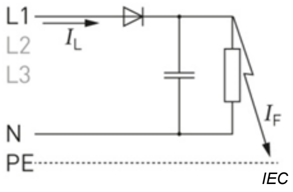
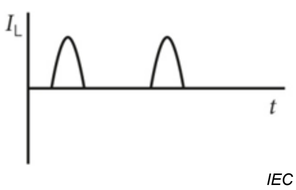
Symbol	RCD type and description
	Type AC (IEC 60417-6148:2012-01): – AC current sensitive; – suitable for Figure H.3, circuits 1 and 2.
	Type A (IEC 60417-6149:2012-01): – AC current sensitive and sensitive to residual pulsating direct currents superimposed on a smooth direct current limited to 6 mA; – suitable for Figure H.3, circuits 1 to 5.
	Type F (IEC 60417-6149:2012-01 + IEC 60417-6160:2012-04): – AC current sensitive and sensitive to residual pulsating direct currents superimposed on a smooth direct current limited to 10 mA; – suitable for Figure H.3, circuits 1 to 6.
	Type B (IEC 60417-6149:2012-01 + IEC 60417-6160:2012-04 + IEC 60417-6297:2014-11): – universal current sensitive; – suitable for Figure H.3, all circuits.

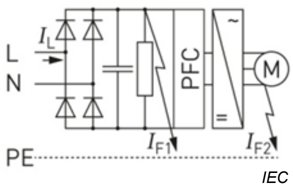
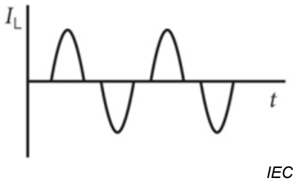
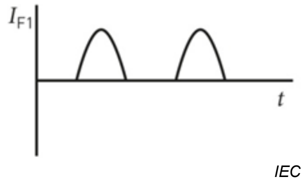
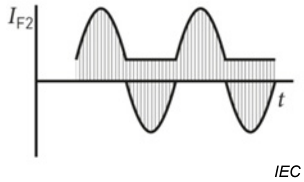
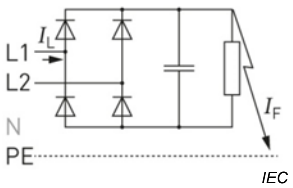
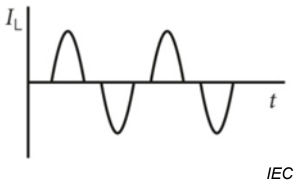
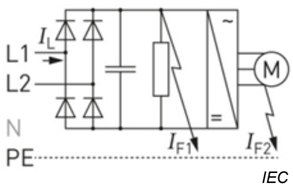
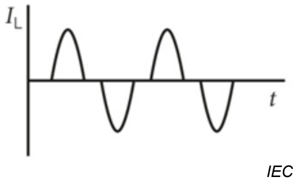
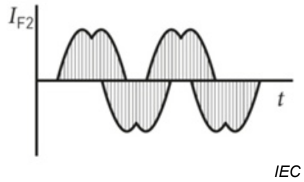
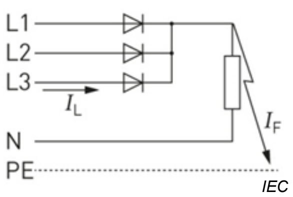
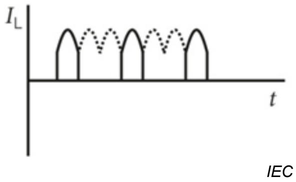
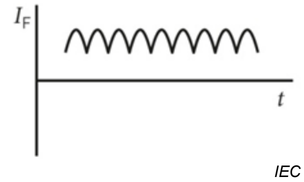
Figure H.2 – Symbols for marking depending on the type of RCD

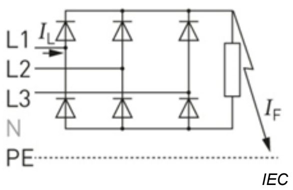
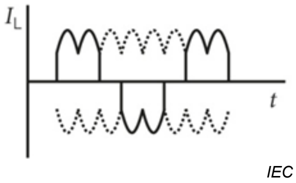
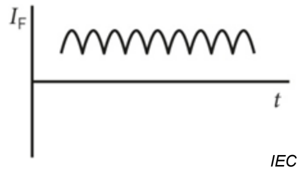
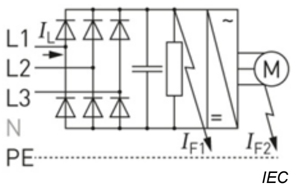
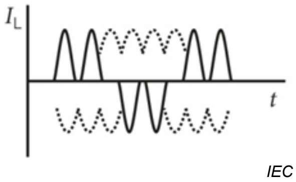
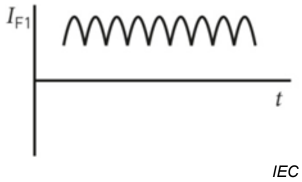
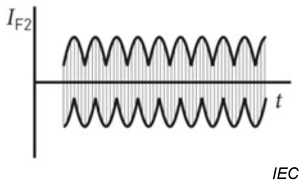
H.2 Fault current waveforms

Figure H.3 shows typical earth fault current waveforms for star point grounded *system*s where a DC component can occur, for different power electronic equipment and *PDS* circuit configurations, used to determine RCD compatibility.

	Circuit diagram with fault location	Shape of load current I_L	Shape of earth fault current I_F	RCD tripping characteristic
1	Phase control 			**AC, A, F, B**
2	Burst control 			**AC, A, F, B**

	Circuit diagram with fault location	Shape of load current I_L	Shape of earth fault current I_F	RCD tripping characteristic
3	Single-phase 			**A, F, B**
4	Two-pulse bridge 			**A, F, B**
5	Two-pulse bridge, half controlled 			**A, F, B**
6	Frequency inverter with two-pulse bridge 		 	**F, B**
7	Single-phase with smoothing 			**B**

	Circuit diagram with fault location	Shape of load current I_L	Shape of earth fault current I_F	RCD tripping characteristic
8	Frequency inverter with two-pulse bridge and power factor correction (PFC) 		 	**B**
9	Two-pulse bridge between phases 			**B**
10	Frequency inverter with two-pulse bridge between phases 		 	**B**
11	Three-phase star 			**B**

	Circuit diagram with fault location	Shape of load current I_L	Shape of earth fault current I_F	RCD tripping characteristic
12	Six-pulse bridge 			**B**
13	Frequency inverter with six-pulse bridge 		 	**B**

Source: IEC 60755:2017, Annex B.

NOTE I_F symbolizes a fault current, not a short-circuit current.

Figure H.3 – Fault current waveforms in connections with *BDM/CDM/PDS*

Annex I
(informative)

Examples of overvoltage category reduction

I.1 General

Figure I.1 to Figure I.13 are intended as illustrations of the requirements in Table 3, Table 6, 4.4.7.2 and 4.4.7.3. They are not intended as indications of good design practice.

- - - - - - - - -	protection to prevent persons from touching *hazardous live parts,* see 4.4.3.3
▬ ▬ ▬ ▬ ▬	conductive *accessible part*s, see 4.4.4.1
-·-·-·-·-·-	*enhanced protection*, see 4.4.5.1
SPD	surge protection device (example of measure to reduce transient overvoltages)
OVC	overvoltage category

I.2 *Protection* to the *surroundings* (see 4.4.7.2)

I.2.1 Circuits connected directly to *mains supply* (see 4.4.7.2.3)

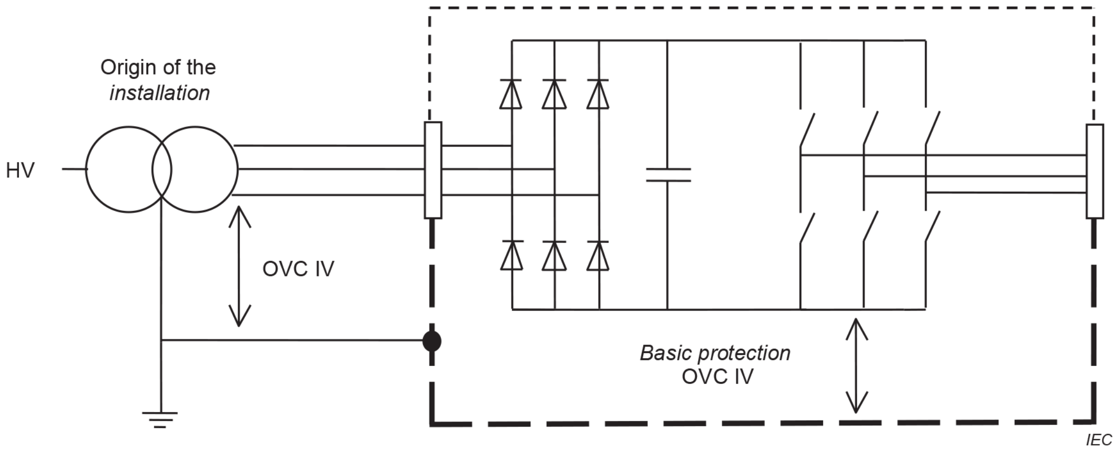


Figure I.1 – *Basic protection* evaluation for circuits connected to the origin of the *installation mains supply*

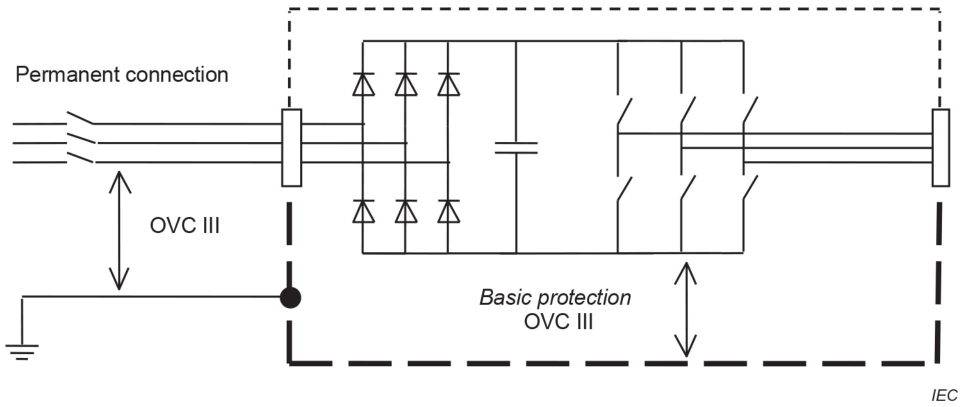


Figure I.2 – *Basic protection* evaluation for circuits connected to the *mains supply*

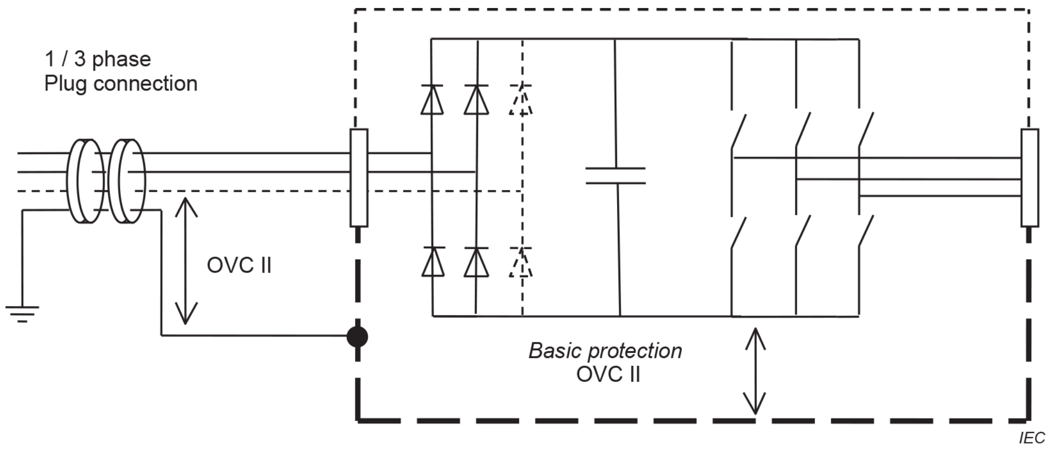


Figure I.3 – *Basic protection* evaluation for single and three phase *BDM/CDM/PDS* not *permanently connected* to the *mains supply*

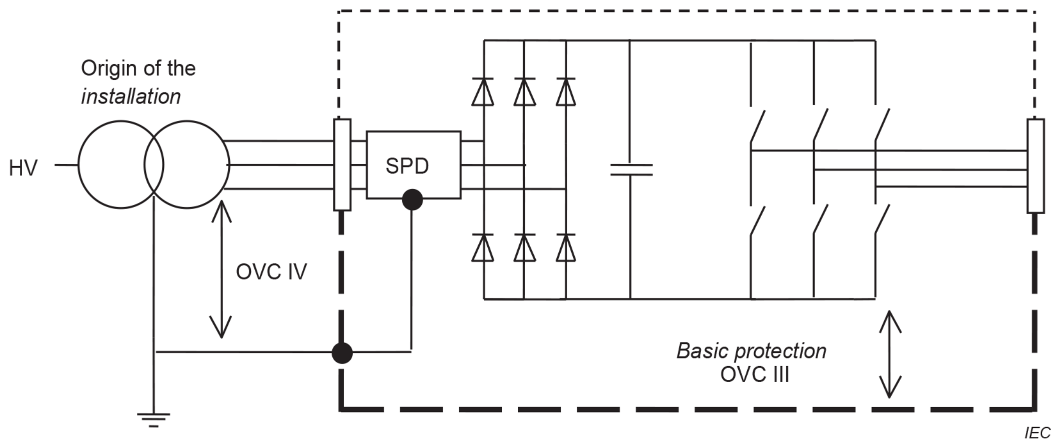


Figure I.4 – *Basic protection* evaluation for circuits connected to the origin of the *installation mains supply* where internal SPDs are used

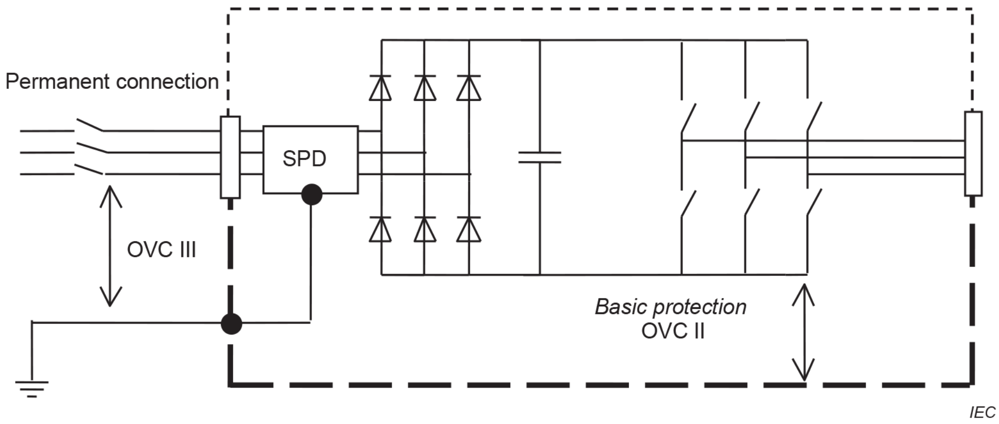


Figure I.5 – *Basic protection* evaluation for circuits connected to the *mains supply* where internal SPDs are used

NOTE For the requirements for reduced *basic protection* downstream of the *SPD*, see 4.4.7.2.3 or 4.4.7.2.4.

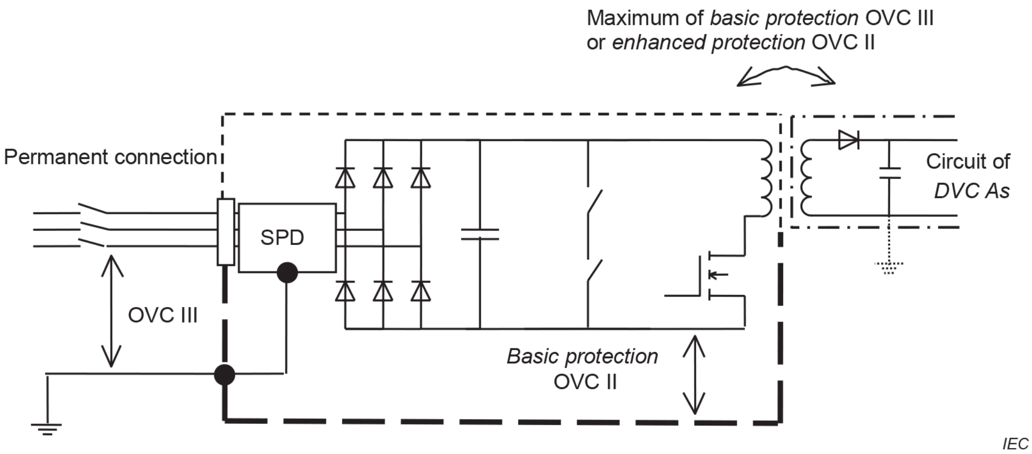


Figure I.6 – Example of *enhanced protection* evaluation for circuits connected to the *mains supply* where internal SPDs are used

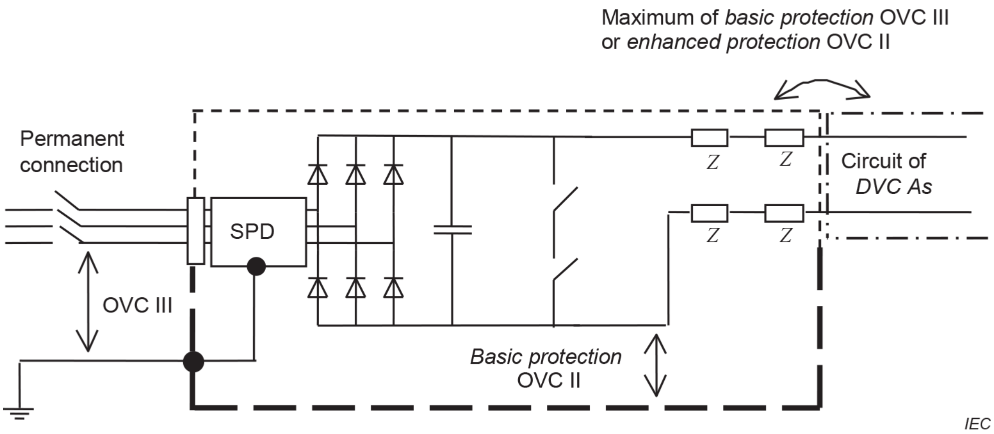


Figure I.7 – Example of *enhanced protection* evaluation for circuits connected to the *mains supply* where internal *SPD*s are used

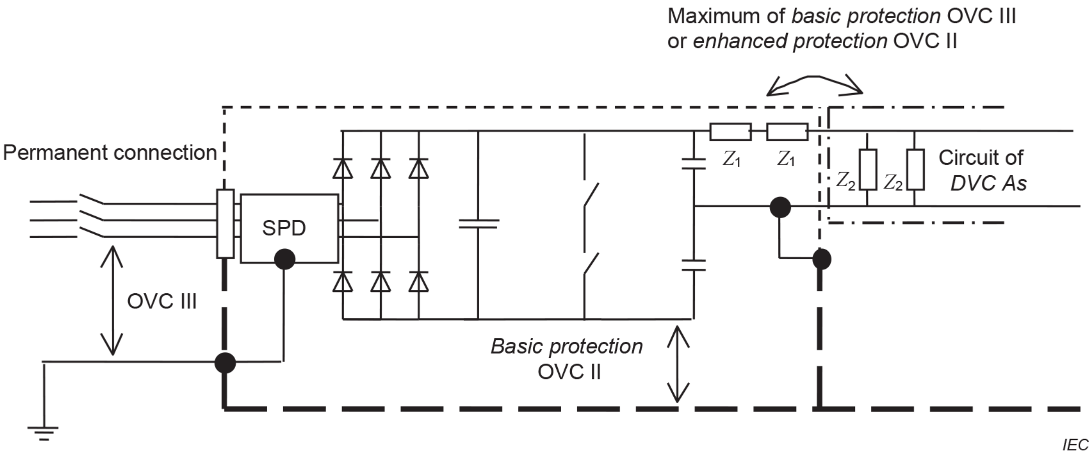


Figure I.8 – Example of *enhanced protection* evaluation for circuits connected to the *mains supply* where internal SPDs are used

NOTE The requirements for *enhanced protection* in Figure I.6 to Figure I.8 are not reduced by the use of the *SPD* (see 4.4.7.2.3 and 4.4.7.2.4).

I.2.2 Circuits connected to the *non-mains supply* (see 4.4.7.2.4)

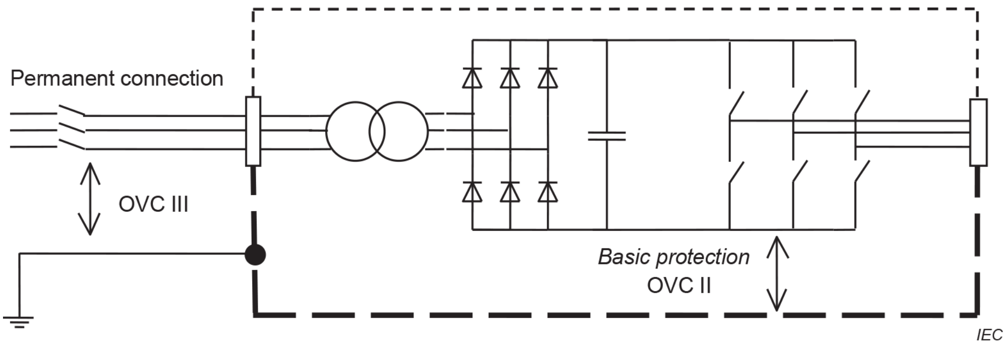


Figure I.9 – *Basic protection* evaluation for circuits connected to the *non-mains supply*

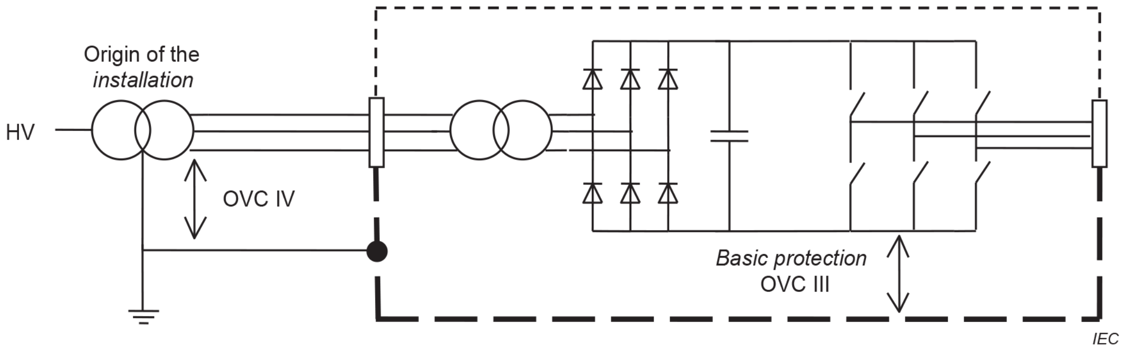
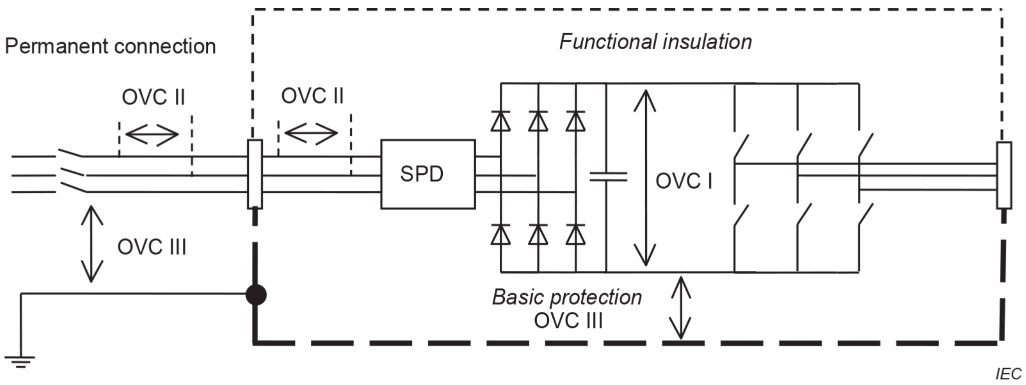


Figure I.10 – *Basic protection* evaluation for circuits connected to the origin of the *installation non-mains supply*

I.2.3 *Insulation* between circuits (see 4.4.7.2.5)

Insulation between two circuits shall be designed according to the circuit having the more severe requirement (see also Figure I.12).

I.3 *Functional insulation* (see 4.4.7.3)



NOTE 1 The *SPD* is not connected to earth, and so has no effect on the overvoltage category to earth.

NOTE 2 The requirements for *functional insulation* can be further reduced by the circuit characteristics (see 4.4.7.3).

Figure I.11 – *Functional insulation* evaluation within circuits affected by external transients

I.4 Further examples

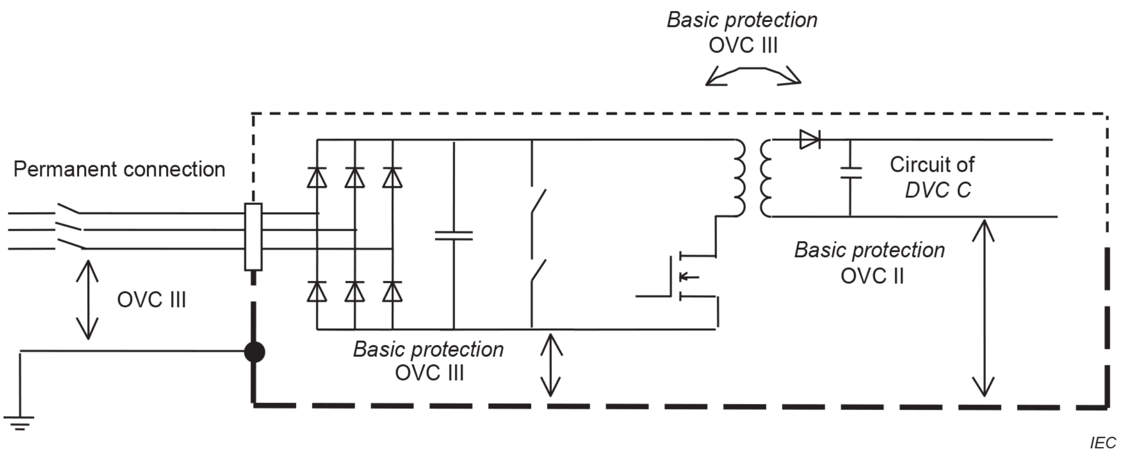


Figure I.12 – *Basic protection* evaluation for circuits connected to the *mains supply* and a non-mains circuit

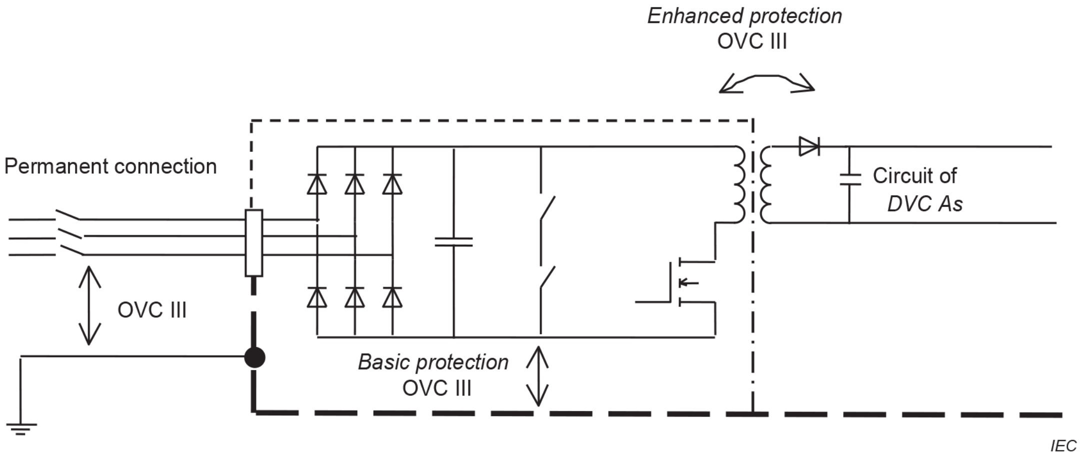


Figure I.13 – *Insulation* evaluation for *accessible circuit* of *DVC As*

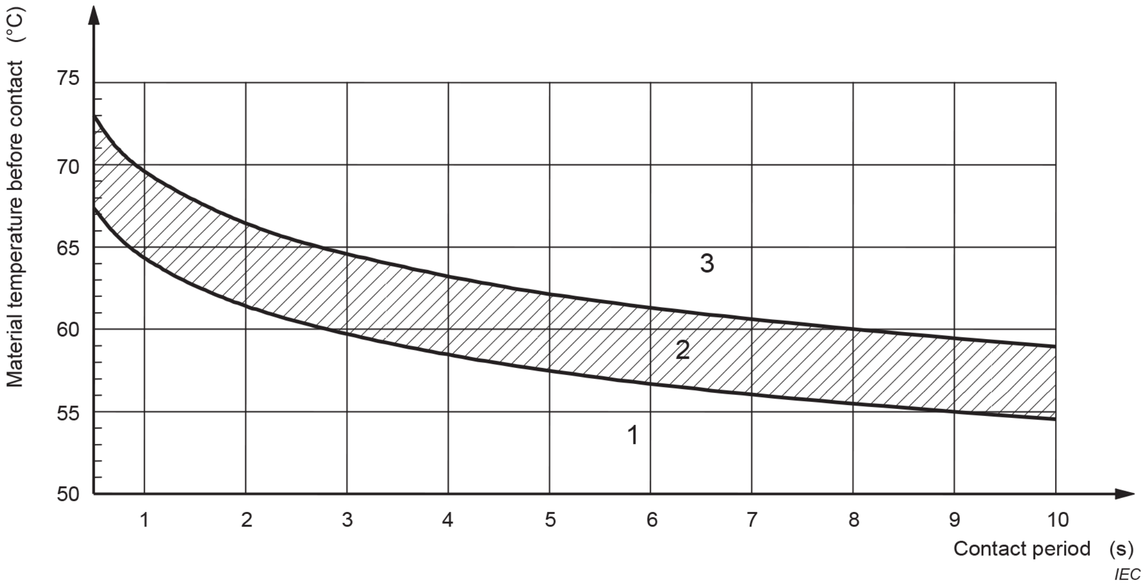
Annex J
(informative)

Burn thresholds for touchable surfaces

J.1 General

Annex J contains information about burn thresholds for touchable surfaces for different materials. Figure J.1, Figure J.2, Figure J.3, Figure J.4 and Figure J.5 are copies of figures from IEC Guide 117:2010.

J.2 Burn thresholds



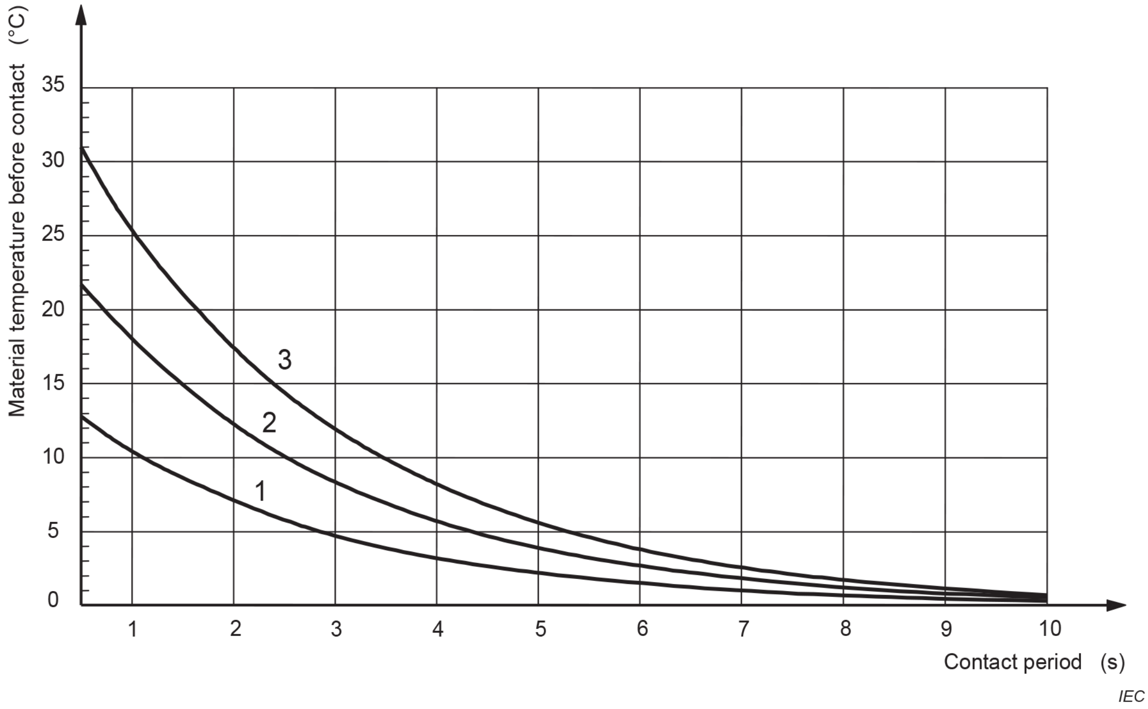
Key

1 no burn

2 burn threshold

3 burn

Figure J.1 – Burn threshold spread when the skin is in contact with a hot smooth surface made of bare (uncoated) metal



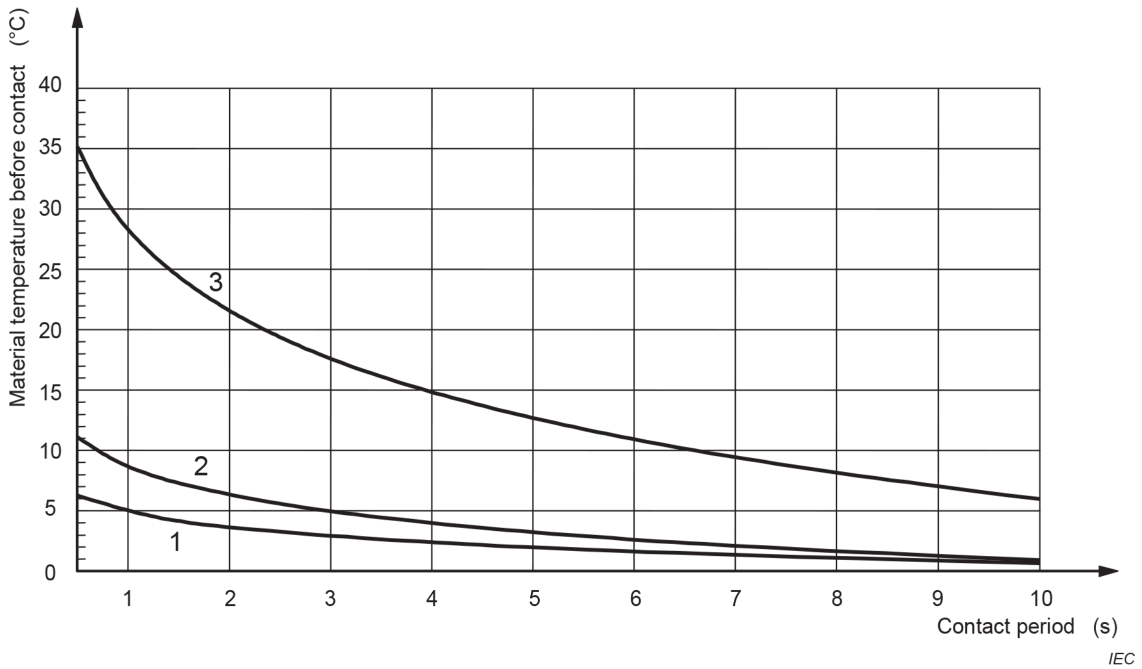
Key

1 coated by shellac varnish of a thickness of 50 µm

2 coated by shellac varnish of a thickness of 100 µm

3 coated by shellac varnish of a thickness of 150 µm

Figure J.2 – Rise in the burn threshold spread from Figure J.1 for metals which are coated by shellac varnish of a thickness of 50 µm, 100 µm and 150 µm



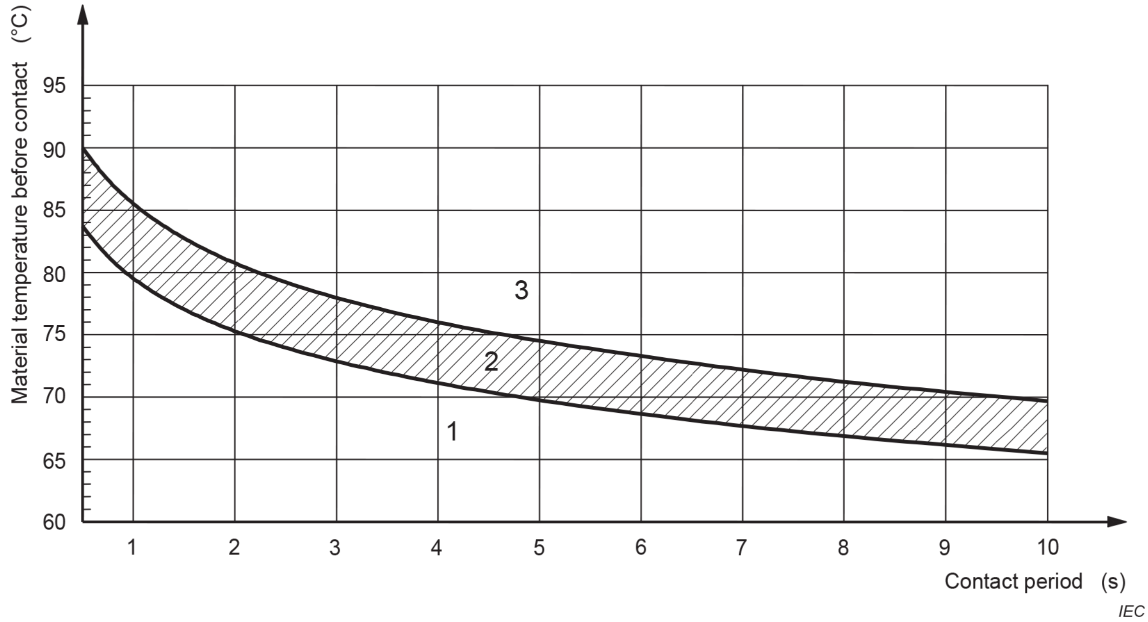
Key

1 porcelain enamel (thickness 160 µm)/powder painted surface (thickness 60 µm)

2 powder painted surface (thickness 90 µm)

3 polyamide 11 or 12 (thickness 400 µm)

Figure J.3 – Rise in the burn threshold spread from Figure J.1 for metals coated with the specific materials



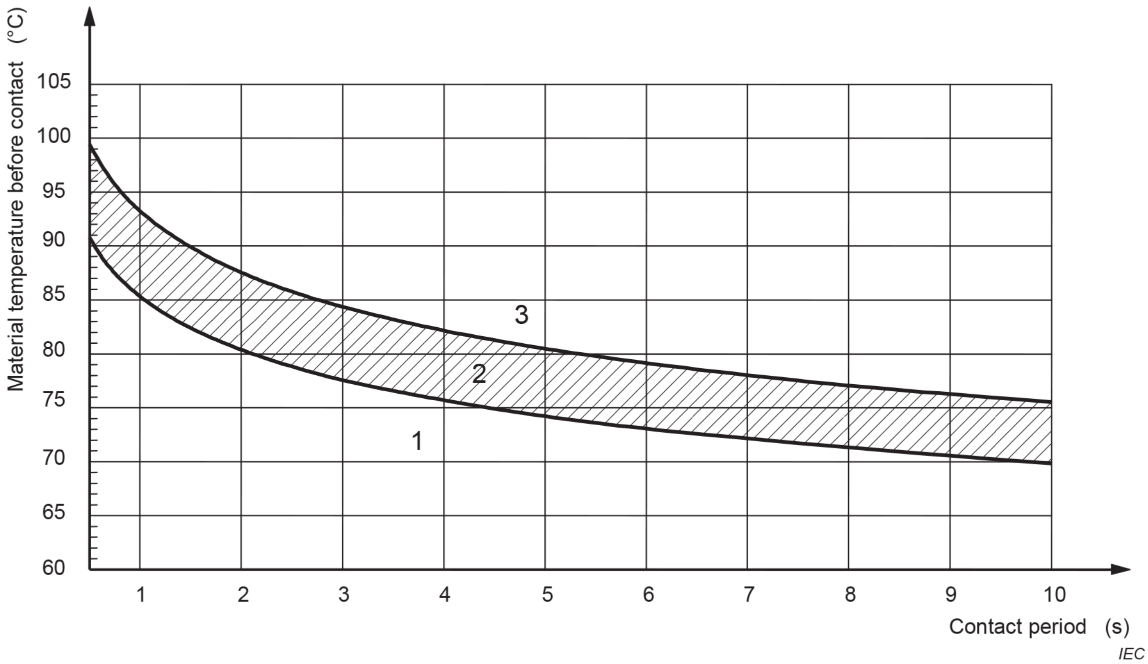
Key

1 no burn

2 burn threshold

3 burn

Figure J.4 – Burn threshold spread when the skin is in contact with a hot smooth surface made of ceramics, glass and stone materials



Key

1 no burn

2 burn threshold

3 burn

Figure J.5 – Burn threshold spread when the skin is in contact with a hot smooth surface made of plastics

Annex K
(informative)

Table of electrochemical potentials

Table K.1 lists electrochemical potentials. Corrosion due to electrochemical action between dissimilar metals that are in contact is minimized if the combined electrochemical potential is below about 0,6 V. In Table K.1, the combined electrochemical potentials are listed for a number of pairs of metals in common use; combinations above the dividing line should be avoided.

Table K.1 – Table of electrochemical potentials

Magnesium, magnesium alloys	Zinc, zinc alloys	80 tin/20 Zn on steel, ZN on iron or steel	Aluminium	Cd on steel	Al/Mg alloy	Mild steel	Duralumin	Lead	Cr on steel, solft solder	CR on Ni on steel, tin on steel 12 % Cr stainless steel	High Cr stainless steel	Copper, copper alloys	Silver solder, Austenitic stainless steel	Ni on steel	Silver	Rh on Ag on Cu, silver/gold alloy	Carbon	Gold, platinum	
0	0,5	0,55	0,7	0,8	0,85	0,9	1,0	1,05	1,1	1,15	1,25	1,35	1,4	1,45	1,6	1,65	1,7	1,75	Magnesium, magnesium alloys
--	0	0,05	0,2	0,3	0,35	0,4	0,5	0,55	0,6	0,65	0,75	0,85	0,9	0,95	1,1	1,15	1,2	1,25	Zinc, zinc alloys
--	--	0	0,15	0,25	0,3	0,35	0,45	0,5	0,5	0,6	0,7	0,8	0,85	0,9	1,05	1,1	1,15	1,2	80 tin/20 Zn on steel, ZN on iron or steel
--	--	--	0	0,1	0,15	0,2	0,3	0,35	0,4	0,45	0,55	0,65	0,7	0,75	0,9	0,95	1,0	1,05	Aluminium
--	--	--	--	0	0,05	0,1	0,2	0,25	0,3	0,35	0,45	0,55	0,6	0,65	0,8	0,85	0,9	0,95	Cd on steel
--	--	--	--	--	0	0,05	0,15	0,2	0,2	0,3	0,4	0,5	0,55	0,6	0,75	0,8	0,85	0,9	Al/Mg alloy
--	--	--	--	--	--	0	0,1	0,15	0,2	0,25	0,35	0,45	0,5	0,55	0,7	0,75	0,8	0,85	Mild steel
--	--	--	--	--	--	--	0	0,05	0,1	0,15	0,25	0,35	0,4	0,45	0,6	0,65	0,7	0,75	Duralumin
--	--	--	--	--	--	--	--	0	0,5	0,1	0,2	0,3	0,35	0,4	0,55	0,6	0,66	0,7	Lead
--	--	--	--	--	--	--	--	--	0	0,05	0,15	0,25	0,3	0,35	0,5	0,55	0,6	0,65	Cr on steel, solft solder
--	--	--	--	--	--	--	--	--	--	0	0,1	0,2	0,25	0,3	0,45	0,5	0,55	0,6	CR on Ni on steel, tin on steel 12 % Cr stainless steel
--							--	--	--	--	0	0,1	0,15	0,2	0,35	0,4	0,45	0,5	High Cr stainless steel
--							--	--	--	--		0	0,05	0,1	0,25	0,3	0,35	0,4	Copper, copper alloys
--							--	--	--	--	--	--	0	0,05	0,2	0,25	0,3	0,35	Silver solder, Austenitic stainless steel
--							--	--	--	--	--	--	--	0	0,15	0,2	0,25	0,3	Ni on steel
--							--	--	--	--	--	--	--	--	0	0,05	0,1	0,15	Silver
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	0,05	0,1	Rh on Ag on Cu, silver/gold alloy
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	0,05	Carbon
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	Gold, platinum

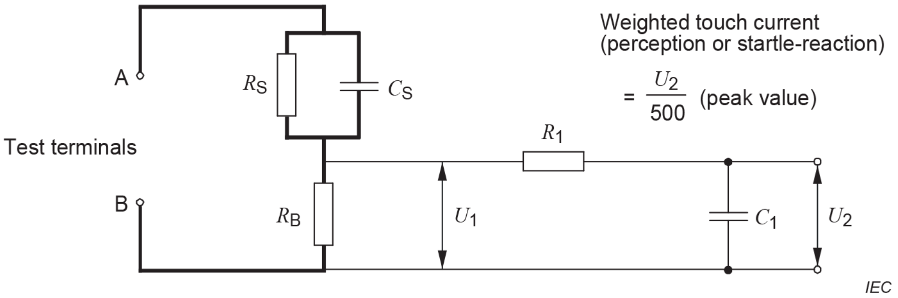
Ag	Silver
Al	Aluminium
Cd	Cadmium
Cr	Chromium
Cu	Copper
Mg	Magnesium
Ni	Nickel
Rh	Rhodium
Zn	Zinc

Annex L
(informative)

Measuring instrument for touch current measurements

L.1 Measuring test circuit

The measuring test circuit of Figure L.1 is from IEC 60990:2016, Figure 4.



Key

R_S	1 500 Ω	R_1	10 kΩ
R_B	500 Ω	C_1	0,022 µF
C_S	0,22 µF		

Figure L.1 – Measuring test circuit

L.2 Requirements for measuring instruments

Electrical measuring instruments shall have adequate bandwidth to provide accurate readings, taking into account all frequency components (DC, AC *mains supply* frequency, high frequency and harmonic content) of the parameter being measured. If the RMS value is measured, care shall be taken that measuring instruments give true RMS readings of non-sinusoidal waveforms as well as sinusoidal waveforms.

Voltmeter or oscilloscope (RMS or peak reading) input resistance: > 1 MΩ .

Input capacitance: < 200 pF.

Frequency range: 15 Hz up to 1 MHz (appropriate for the highest frequency of interest).

Annex M
(normative)

Test probes for determining access

Figure M.1 to Figure M.4 are reproduced from IEC 61032:1997 for convenience only.

This test probes are used for the non-accessibility test (*type test*) in 5.2.2.2 and the steady force test in 5.2.2.4.2.2.

All dimensions in the following figures are in millimetres.

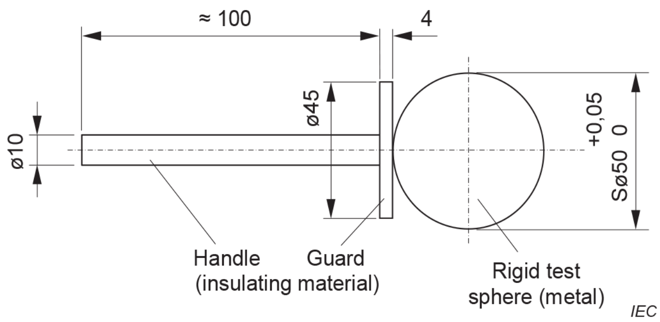
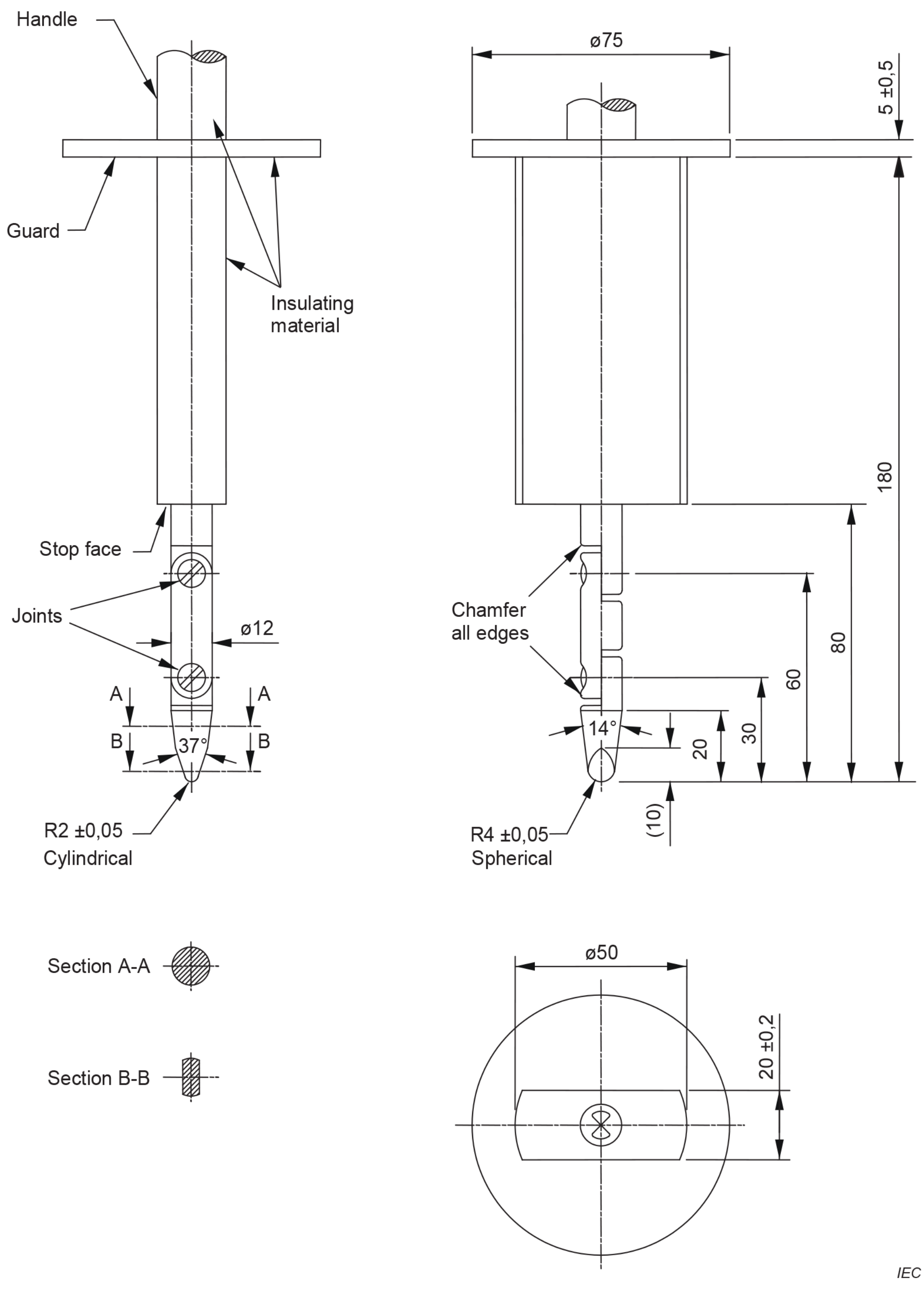


Figure M.1 – Sphere 50 mm probe according to IEC 61032:1997, test probe A



Material: metal, except where otherwise specified.

Tolerance on dimensions when no specific tolerance is given:

– on angles: –10'

– on linear dimensions: up to 25 mm: –0,05 mm; over 25 mm: ± 0,2 mm.

Both joints shall permit movement in the same plane and the same direction through an angle of 90° with a 0° to +10° tolerance.

Figure M.2 – Jointed test finger according to IEC 61032:1997, test probe B

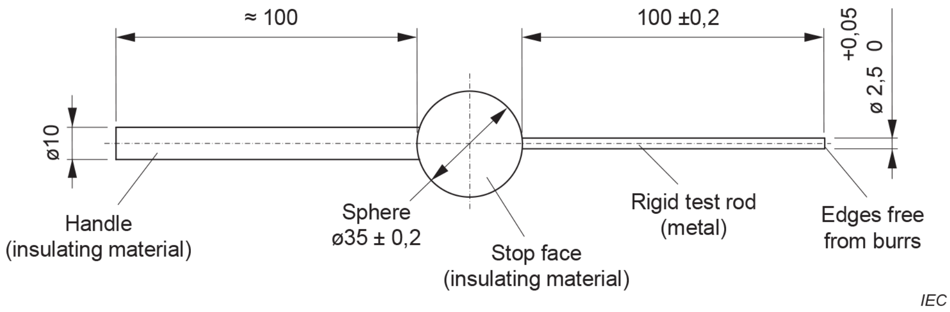


Figure M.3 – Test rod 2,5 mm according to IEC 61032:1997, test probe C

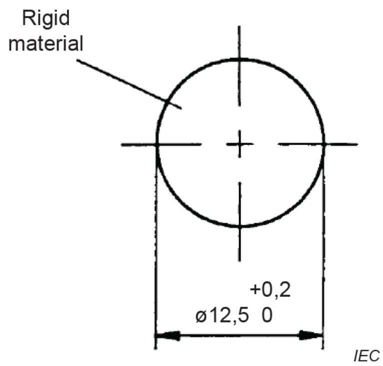


Figure M.4 – Sphere 12,5 mm test probe according to IEC 61032:1997, test probe 2

Annex N
(informative)

Guidance regarding short-circuit current

For more information please refer to IEC 62477-1:2022.

Annex O
(informative)

Guidance for determination of *clearance* and *creepage distance*

O.1 Guideline for determination of *clearance*

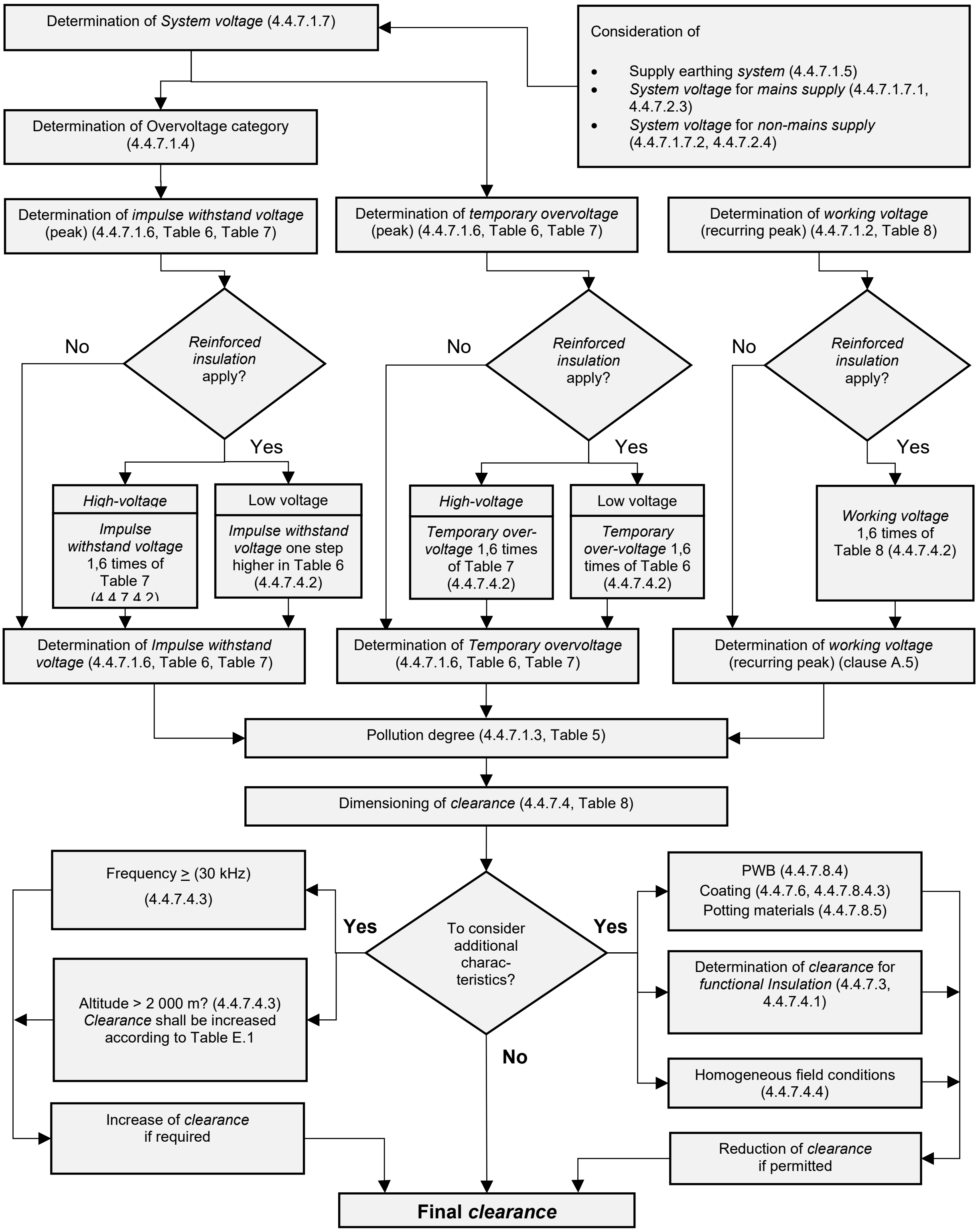


Figure O.1 – Flowchart *clearance*

O.2 Guideline for determination of *creepage distance*

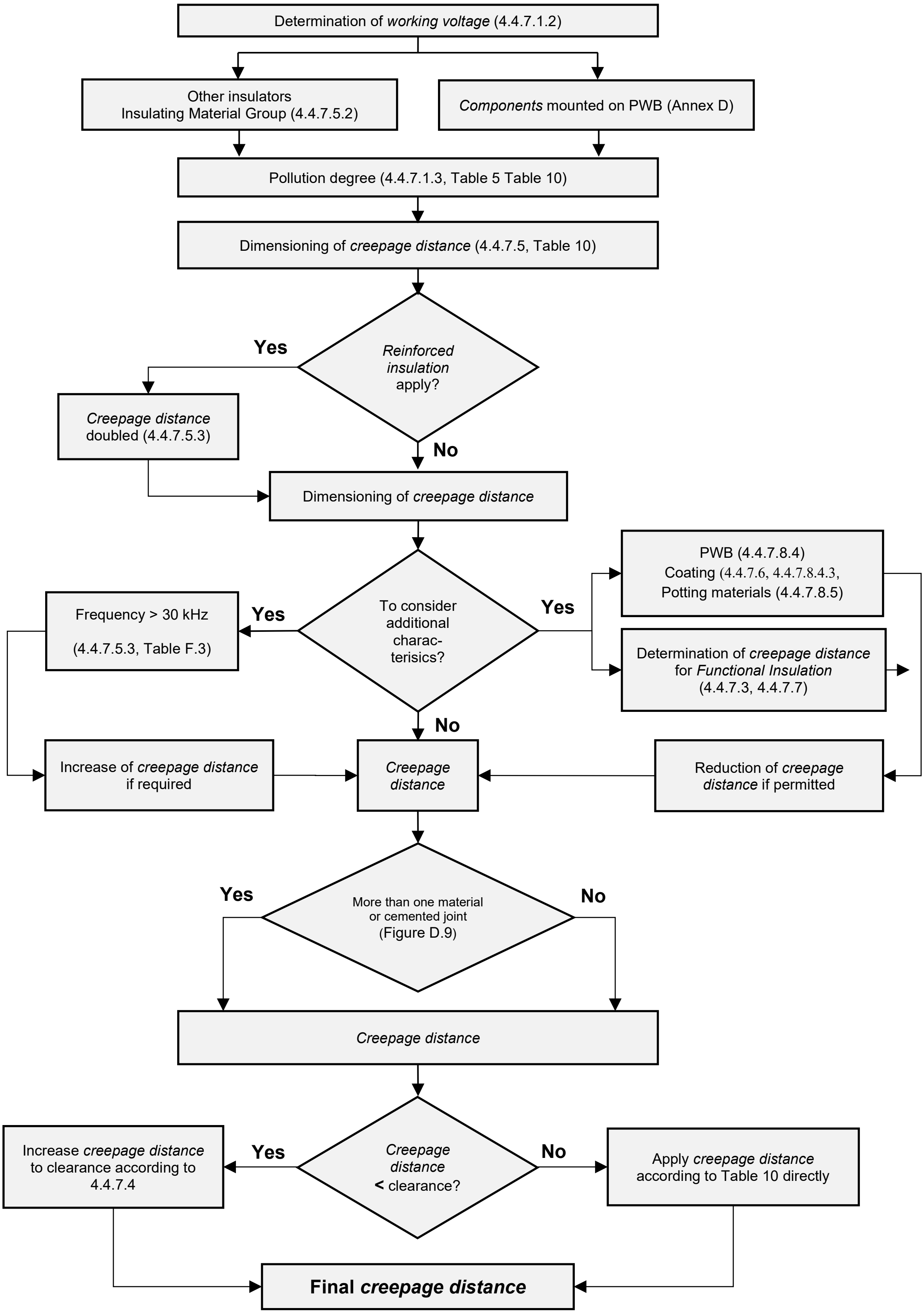


Figure O.2 – Flowchart *creepage distance*

O.3 Minimum *clearance* and *creepage distances* for material

Source: IEC 60664-3:2016, 4.4.

For type 2 protection in 4.4.7.8.4.3, inner layer of PWB in 4.4.7.8.4.2 and cemented joints in 4.4.7.9, the *clearance* and *creepage distances* between the conductors before the protection is applied shall not be less than the values as specified in Table O.1, which is reproduced from IEC 60664-3:2016, Table 1. These values apply to *basic insulation*, *supplementary insulation* as well as *reinforced insulation*. These values may also be applied to *functional insulation*.

The determined maximum peak value of the voltage from 4.4.7.4 (crest value of *temporary overvoltage* or recurring peak of *working voltage*) shall be used as input to Table O.1.

Table O.1 – Minimum *clearance* and *creepage distances* for material

Maximum peak value of any voltage [a] kV	**Minimum *clearance* and *creepage distances*** mm
≤ 0,33	0,01
> 0,33 and ≤ 0,4	0,02
> 0,4 and ≤ 0,5	0,04
> 0,5 and ≤ 0,6	0,06
> 0,6 and ≤ 0,8	0,1
> 0,8 and ≤ 1,0	0,15
> 1,0 and ≤ 1,2	0,2
> 1,2 and ≤ 1,5	0,3
> 1,5 and ≤ 2,0	0,45
> 2,0 and ≤ 2,5	0,6
> 2,5 and ≤ 3,0	0,8
> 3,0 and ≤ 4,0	1,2
> 4,0 and ≤ 5,0	1,5
> 5,0 and ≤ 6,0	2
> 6,0 and ≤ 8,0	3
> 8,0 and ≤ 10	3,5
> 10 and ≤ 12	4,5
> 12 and ≤ 15	5,5
> 15 and ≤ 20	8
> 20 and ≤ 25	10
> 25 and ≤ 30	12,5
> 30 and ≤ 40	17
> 40 and ≤ 50	22
> 50 and ≤ 60	27
> 60 and ≤ 80	35
> 80 and ≤ 100	45

Source: IEC 60664-3:2016, Table 1.

Linear interpolation is permitted.

[a] Transient overvoltages are disregarded since they are unlikely to degrade the protected assembly.

Annex P
(normative)

Protection of persons against electromagnetic fields for frequencies from 0 Hz up to 300 GHz

NOTE Annex P is added as a normative requirement to show compliance with the requirements of the European low voltage directive.

P.1 General influence of electromagnetic fields to persons

P.1.1 General

(source: World Health Organisation, modified)

Exposure to electromagnetic fields is not a new phenomenon. However, during the 20th century, environmental exposure to man-made electromagnetic fields has been steadily increasing as growing electricity demand, ever-advancing technologies and changes in social behaviour have created more and more artificial sources. Everyone is exposed to a complex mixture of weak electric and magnetic fields, both at home and at work. Typical sources of electromagnetic fields are generation and transmission of electricity, domestic appliances and industrial equipment, as well as telecommunications and broadcasting.

Tiny electrical currents exist in the human body due to the chemical reactions that occur as part of the normal body functions, even in the absence of external electric fields. For example, nerves transfer signals by transmitting electric impulses. Many biochemical reactions from digestion to brain activities go along with the rearrangement of charged particles. Even the heart is electrically active – an activity that your doctor can visualize by an electrocardiogram.

P.1.2 Low-frequency electric field effects (1 Hz to 100 kHz)

Low-frequency electric fields influence the human body just as they influence any other material made up of charged particles. When electric fields act on conductive materials, they influence the distribution of electric charges at their surface. They cause current to flow through the body to the ground.

P.1.3 Low-frequency magnetic field effects (1 Hz to 100 kHz)

Low-frequency magnetic fields induce circulating currents within the human body. The strength of these currents depends on the intensity of the external magnetic field. If sufficiently large, these currents could cause stimulation of nerves and muscles or induce visual sensations, so-called magnetophosphenes.

P.1.4 Low-frequency electric and magnetic field effects

Both electric and magnetic fields induce voltages and currents in the body, but even directly beneath a high-voltage transmission line, the induced currents are very small compared to thresholds for producing electric shock and other electrical effects.

P.1.5 High-frequency electromagnetic field effects (100 kHz to 300 GHz)

Heating of tissue is the main biological effect of the electromagnetic fields with frequencies greater than 100 kHz up to 300 GHz. In microwave ovens, this fact is employed to heat food. The levels of radiofrequency fields to which people are normally exposed are very much lower than those needed to produce significant heating. The heating effect of radio waves forms the underlying basis for current high frequency guidelines.

P.1.6 Current knowledge on low-level effects

Scientists are also investigating the possibility that effects below the threshold level for body heating occur as a result of long-term exposure. Independent international expert bodies claim that the overall evaluation of all the research on high frequency fields leads to the conclusion that high frequency exposure below the thermal threshold is unlikely to be associated with adverse health effects.

P.1.7 Biological effects versus adverse health effects

Biological effects are measurable responses to a stimulus or to a change in the environment. These changes are not necessarily harmful for the health of persons. For example, listening to music, reading a book, eating an apple or playing tennis will produce a range of biological effects. Nevertheless, none of these activities is expected to cause any adverse health effects. The body has sophisticated mechanisms available to deal with the manifold influences we encounter in our environment. Ongoing change forms a normal part of our lives. But, of course, the body does not possess adequate compensation mechanisms for all biological effects.

An adverse health effect causes detectable impairment of the health of the exposed individual or of his or her offspring; a biological effect, on the other hand, may or may not result in an adverse health effect.

It is not disputed that electromagnetic fields above certain levels can cause acute biological effects. Experiments with healthy volunteers indicate that short-term exposure at the levels present in the environment or in the home do not cause any apparent detrimental effects. Exposures to higher levels that might be harmful are restricted by national and international guidelines. The current debate is centred on whether long-term low level exposure can evoke biological responses and influence people's well-being.

P.1.8 Influence of EMF on passive and active medical implants

Electromagnetic fields can influence passive and active medical implants through field exposure. Passive conductive implants can be heated by eddy currents induced by external fields. The function of active medical implants, for example cardiac pacemakers, can be influenced by external fields. As interference effects might occur even at exposure levels below the general public exposure limit values, special considerations have to be taken for the protection of patients with active or passive medical implants.

P.2 Recommendations from ICNIRP Guidelines against exposure to EMF

P.2.1 Adoption of exposure limits from ICNIRP

P.2.1.1 General

Recommendations on human exposure to EMF have been published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). Guidance in Annex P is based upon

- ICNIRP's EMF guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz) published in 2010 which provide limits from 1 Hz up to 10 MHz,
- ICNIRP's guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz) published in 1998 which provide limits from 0 Hz up to 300 GHz where the values from 0 Hz to 1 Hz are used, and
- European workers directive 2013/35/EU which provide limits for static magnetic fields.

However, due to experience based on EMC tests, emission of electromagnetic fields above 10 MHz is not considered relevant for *PDS*. Therefore, Annex P provide limits for frequencies from 0 Hz up to 10 MHz.

ICNIRP recommends a two-step *system* of limit values. The basic restrictions in ICNIRP and in the European workers directive 2013/35/EU for low frequency exposure are based on induced electric fields inside the human body. These basic restrictions already contain a sufficient safety factor to the actual adverse health effects threshold. As these basic restrictions are not measurable and only computable with great efforts, ICNIRP and the European workers directive 2013/35/EU derived easily measurable reference values in terms of external electric or magnetic fields. Compliance with these reference values ensures compliance with the basic restrictions even under worst-case exposure situations.

The safety concept described in Annex P is based on the reference values only. This specification adds a significant amount of conservatism to the already conservative ICNIRP and the European workers directive 2013/35/EU approach. In addition, the safety concept described in Annex P is based on reference values for the whole body exposure only. Compliance with the whole body reference values implies compliance with the less restrictive reference values for limbs and extremities.

When *PDS* are de-energized, no electromagnetic fields exceeding the limits of Table P.1 or Table P.2 are expected, except where permanent magnets are part of the *PDS*. In this case, the limits of Table P.3 shall be taken into account.

P.2.1.2 EMF limits during operation

The limits of Table P.1, Table P.2 and Table P.3 are applicable for continuous exposure.

Where fields are produced by switching waveforms within the *PDS*, multiple frequencies will be present simultaneously. In this case, a weighted peak summation of the spectrum according to ICNIRP guidelines or equivalent shall be used for evaluation of the field exposure with respect to the limit.

NOTE Equivalent procedures can be defined in national regulations (e.g. Germany national regulation DGUV 15).

Table P.1 – Limits of EMF for general public exposure

Frequency range	Electric field strength kV/m	Magnetic field strength A/m	Magnetic flux density T
0 Hz to 1 Hz [a]	--	$3,2 \times 10^4$	4×10^{-2}
1 Hz to 8 Hz	5	$3,2 \times 10^4/f^2$	$4 \times 10^{-2}/f^2$
8 Hz to 25 Hz	5	$4 \times 10^3/f$	$5 \times 10^{-3}/f$
25 Hz to 50 Hz	5	$1,6 \times 10^2$	2×10^{-4}
50 Hz to 400 Hz	$2,5 \times 10^2/f$	$1,6 \times 10^2$	2×10^{-4}
400 Hz to 3 kHz	$2,5 \times 10^2/f$	$6,4 \times 10^4/f$	$8 \times 10^{-2}/f$
3 kHz to 10 MHz	$8,3 \times 10^{-2}$	21	$2,7 \times 10^{-5}$

f in Hz.

Values are valid for sinusoidal frequency exposure.

Values are taken from ICNIRP guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz) published in 2010, Table 4.

[a] Values are taken from ICNIRP guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz) published in 1998, Table 7).

Table P.2 – Limits of EMF for occupational exposure

Frequency range	Electric field strength kV/m	Magnetic field strength A/m	Magnetic flux density T
0 Hz to 1 Hz [a]	--	$1{,}63 \times 10^{5}$	0,2
1 Hz to 8 Hz	20	$1{,}63 \times 10^{5}/f^{2}$	$0{,}2/f^{2}$
8 Hz to 25 Hz	20	$2 \times 10^{4}/f$	$2{,}5 \times 10^{-2}/f$
25 Hz to 300 Hz	$5 \times 10^{2}/f$	8×10^{2}	1×10^{-3}
300 Hz to 3 kHz	$5 \times 10^{2}/f$	$2{,}4 \times 10^{5}/f$	$0{,}3/f$
3 kHz to 10 MHz	$1{,}7 \times 10^{-1}$	80	1×10^{-4}

f in Hz.

Values are valid for sinusoidal frequency exposure.

Values are taken from ICNIRP guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz) published in 2010, Table 3).

[a] Values are taken from ICNIRP guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz) published in 1998, Table 6).

Table P.3 – Limits for magnetic flux density of static magnetic fields

Potential hazards	Magnetic flux density mT
Interference with active medical implanted devices, for example cardiac pacemakers	0,5
Attraction and projectile risk due to permanent magnets	3
Values are taken from European Directive 2013/35/EU, Table B4.	

P.2.2 Limits of EMF exposure for transportation and storage

During transport and storage, the *BDM/CDM/PDS* is de-energized. The limits of Table P.3 might still apply.

Information shall be provided to ensure protection of persons:

- the required distance in product package as well as without package; or
- other means.

P.3 Protection of persons against exposure of EMF

P.3.1 General

In Clause P.3, the limits from ICNIRP in Clause P.2 are adopted to match the conditions of *PDS*.

The following conditions shall be taken into account:

- normal operating conditions and *abnormal operating conditions* in
  - general public access areas, and
  - *general-access areas*, *service-access areas* and *restricted-access areas*;
- passive and active medical implants;
- transportation and storage.

For requirements, see P.3.2, P.3.3 or P.3.4.

For compliance, see P.4.2.

For marking, see Clause P.5.

P.3.2 EMF requirements for general public access areas

During normal operating conditions and *abnormal operating conditions*, pluggable enclosed *PDS* intended to be used in general public access areas shall not exceed the limits from

a) Table P.1 to protect persons with and without passive implants, and

b) Table P.3 to protect persons with active medical implants (cardiac pacemaker).

NOTE Some countries have individual limits, for example Germany with 0,1 mT/50 Hz for active medical implants in the 26. BImschV (Bundesimmisionsschutz Verordnung der Bundesrepublik Deutschland).

The limits are valid at a distance of 0 cm from the surface of the *BDM/CDM/PDS*.

For *permanently connected PDS,* means may be required in the documentation to meet the requirements.

P.3.3 EMF requirements for *general-access areas*, *service-access areas* and *restricted-access areas*

During normal operating conditions and *abnormal operating conditions*, enclosed PDS intended to be used in *general-access areas*, *service-access areas* and *restricted-access areas* shall not exceed the limits from

- Table P.2 to protect persons with and without passive implants, and
- Table P.3 to protect persons with active medical implants (cardiac pacemaker) if applicable.

The limits are valid at a distance of 25 cm from the surface.

NOTE The distance is selected according to EN 12198-1:2000 and EN 12198-1:2000/AMD1:2008, Clause B.4.

For *open type BDM/CDM*, information about means for protection shall be provided in the documentation, for example use of ferrous metal switchgear cabinets or distance.

For marking, see Clause P.5.

P.3.4 EMF requirements for transportation and storage

During transport and storage, the *PDS* is de-energized; however, the limits from Table P.3 apply when permanent magnets are provided as part of the *PDS*.

The limits are valid at a distance of 25 cm from the surface unpacked or at a distance of 0 cm from the surface of the packaging.

If greater distances are required, this shall be stated in the documentation.

NOTE 1 The distance is selected according to EN 12198-1:2000 and EN 12198-1:2000/AMD1:2008, Clause B.4.

The force due to static magnetic fields shall be taken into account.

NOTE 2 The sources of static magnetic fields are, for example, linear motors or single magnetic *components*.

P.4 Electromagnetic fields (EMF) test (*type test*)

P.4.1 General test set up for EMF

When required in P.3.2, P.3.3 or P.3.4, calculation, simulation or tests according to Table P.4 shall be performed in a distance from the floor to cover the body of the person to protect, and the *PDS* is energized, to demonstrate compliance with the requirements.

The measuring duration shall be not less than 1 s in a distance as specified in the applicable P.3.2, P.3.3 or P.3.4. Use of weighted peak sensors or sensor with averaging of nearly 100 cm^2 are permitted.

In known applications, typical length of physical presence of persons may be taken into account.

See IEC 62311 or EN 12198 (all parts) for more information.

P.4.2 EMF test

Calculation, simulation or tests shall be performed according to Table P.4.

Table P.4 – EMF test overview

Access area	Requirements	Other means permitted
General public access area	Table P.1 and Table P.3	No
General-access areas, service-access areas and *restricted access areas*	Table P.2 and Table P.3	Yes, for example distances or time of exposure
Transportation and storage	Table P.3	Yes, for example distances or time of exposure

P.5 Electromagnetic fields (EMF) marking

When required in P.3.1, P.3.2, or P.3.3, the *BDM/CDM/PDS* shall be marked with the warning symbol ISO 7010-W001:2011-05 or ISO 7000-0434a:2004-01 or ISO 7000-0434b:2004-01 (see Table C.1) and the documentation shall provide the following information.

For operation:

- the claimed level of protection according to the applicable Table P.1, Table P.2 or Table P.3; or
- other required means in the *installation*, for example distance or time of exposure.

For transport and storage:

- required distances in product package as well as without package; or
- other required means; and
- handling information due to the force caused by the static magnetic field.

Annex Q
(informative)

Automatic disconnection of supply

Q.1 Maximum disconnection times

For information, 411.3.2.2, 411.3.2.3, 411.3.2.4, 415.2.1 and 415.2.2 were reproduced from IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017.

NOTE The clause numbering of this Annex Q is taken from the source standard and cannot be modified.

411.3.2 Automatic disconnection in case of a fault

411.3.2.1 A protective device shall automatically switch off the supply to the line conductor of a circuit or equipment in the event of a fault of negligible impedance between the line conductor and an exposed-conductive-part or a protective conductor in the circuit or equipment within the disconnection time required in 411.3.2.2, 411.3.2.3 or 411.3.2.4.

The device shall be suitable for isolation of at least the line conductor(s).

411.3.2.2 The maximum disconnection time stated in Table 41.1 shall be applied to final circuits with a rated current not exceeding

- 63 A with one or more socket-outlets, and
- 32 A supplying only fixed connected current-using equipment.

NOTE 1 "Fixed connected" in IEC 60364-4-41 is equivalent to "*permanently connected*" in this document.

NOTE 2 "Protective conductor" is equivalent to "*PE conductor*" in this document.

NOTE 3 "Line" is is equivalent to "phase" in this document.

Table 41.1 – Maximum disconnection times

System	50 V < U_o ≤ 120 V s		120 V < U_o ≤ 230 V s		230 V < U_o ≤ 400 V s		U_o > 400 V s	
	AC	**DC**	**AC**	**DC**	**AC**	**DC**	**AC**	**DC**
TN	0,8	--[a]	0,4	1	0,2	0,4	0,1	0,1
TT	0,3	--[a]	0,2	0,4	0,07	0,2	0,04	0,1

Where in TT systems the disconnection is achieved by an overcurrent protective device and the *protective equipotential bonding* is connected with all extraneous-conductive-parts within the installation, the maximum disconnection times applicable to TN systems may be used.

U_o is the nominal AC or DC line to earth voltage.

NOTE Where disconnection is provided by an RCD see Note to 411.4.4, Note 4 to 411.5.3 and Note to 411.6.4 b).

[a] Disconnection may be required for reasons other than protection against electric shock.

411.3.2.3 In TN systems, a disconnection time not exceeding 5 s is permitted for distribution circuits, and for circuits not covered by 411.3.2.2.

411.3.2.4 In TT systems, a disconnection time not exceeding 1 s is permitted for distribution circuits and for circuits not covered by 411.3.2.2.

Q.2 Supplementary *protective equipotential bonding*

NOTE 1 Supplementary *protective equipotential bonding* is considered as an addition to fault protection.

NOTE 2 The use of supplementary protective bonding does not exclude the need to disconnect the supply for other reasons, for example protection against fire, thermal stress in equipment, etc.

NOTE 3 Supplementary protective bonding can involve the entire installation, a part of the installation, an item of apparatus, or a location.

NOTE 4 Additional requirements can be necessary for special locations (see the corresponding part of the IEC 60364-7 series) or for other reasons.

415.2.1 Supplementary *protective equipotential bonding* shall include all simultaneously accessible exposed-conductive-parts of fixed equipment and extraneous-conductive-parts including where practicable the main metallic reinforcement of constructional reinforced concrete. The equipotential bonding system shall be connected to the protective conductors of all equipment including those of socket-outlets.

NOTE 1 "Fixed connected" in IEC 60364-4-41 is equivalent to "*permanently connected*" in this document.

NOTE 2 "Protective conductor" is equivalent to "*PE conductor*" in this document.

NOTE 3 "Exposed-conductive-part" is equivalent to "conductive *accessible part*" in this document.

NOTE 4 "Extraneous-conductive-part" is "a conductive part of equipment which can be touched and which is not a *live part*, but which may become live under fault conditions".

415.2.2 The resistance R between simultaneously accessible exposed-conductive-parts and extraneous-conductive-parts shall fulfil the following condition:

$$R \leq \frac{50\ \text{V}}{I_\text{a}} \quad \text{in AC systems}$$

$$R \leq \frac{120\ \text{V}}{I_\text{a}} \quad \text{in DC systems}$$

where

I_a is the operating current in A of the protective device:

– for residual current protective devices (RCDs), $I_{\Delta\text{n}}$;

– for overcurrent devices, the 5 s operating current.

Annex R
(informative)

Risk assessment according to IEC Guide 116

R.1 General

The purpose of this Annex R is to provide the user of this document with an overview of potential hazards according to IEC Guide 116.

This overview might be useful for the user during the risk evaluation according to 4.2.

If a hazard is present but risk mitigation of this hazard is not covered by this document, other standards, publications or literature describing available state-of-art knowledge should be used.

R.2 Risk assessment

Table R.1 provides an overview about the risk assessment.

Table R.1 – Risk assessment

Requirement	Relevant yes/no?	Fulfilled by
A.2 Preliminary observations	Yes	Application of IEC Guide 116:2018, Annex A
A.3 Safety integration	Yes	Application of IEC Guide 116, in particular application of the "3-step-method": – inherent design measures; – protective measures; – user information.
A.4 Protection against electrical hazards		4.1, 4.2, 4.4, 4.5, 4.8, 4.9, 4.11, 4.12, 4.13, Annex A, Annex D, Annex E, Annex F, Annex M
Leakage current	Yes	4.4.4.3.3, 4.4.5.4, 4.4.8
Energy supply	Yes	4.4.7.1 to 4.4.7.2, 4.8
Stored charges	Yes	4.4.9, 4.5
Arcs	Yes	4.4.7.8.2
Electric shock	Yes	4.1, 4.2, 4.4, 4.5, 4.8, 4.9, 4.11, 4.12, 4.13, Annex A, Annex D, Annex E, Annex F, Annex M
Burns (DC and high frequency)	Yes	4.4.4.4, 4.4.5.4
A.5 Protection against mechanical hazards		4.1, 4.2, 4.7, 4.9, 4.12
Instability	Yes	4.12.5
Break-down during operation	Yes	4.12.1 to 4.12.4
Falling or ejected objects	Yes	4.4.4.3.3, 4.7.5.3
Inadequate surfaces, edges or corners	Yes	4.7.6
Moving parts, especially where there may be variations in the rotational speed of parts	Yes	4.7.5.2
Vibration	Yes	4.9
Improper fitting of parts	Yes	4.11.6
A.6 Protection against other hazards		4.1, 4.2, 4.10, 4.14

Requirement	Relevant yes/no?	Fulfilled by
A.6.2 Explosion	No	
A.6.3 Hazards arising from electric, magnetic, and electromagnetic fields, other ionising and non-ionising radiation	Yes	4.14
A.6.4 Electric, magnetic, and electromagnetic disturbances	Yes	Not covered
A.6.5 Optical radiation	No	
A.6.6 Fire	No	
A.6.6.1 Break down of *component* (*single-fault condition*)	Yes	4.2, 4.5.3
A.6.6.2 Short-circuit and overload protection (*single-fault condition*)	Yes	4.2, 4.3
A.6.7 Temperature	Yes	4.6.5
A.6.8 Acoustic noise	Yes	4.10
A.6.9 Biological and chemical effects	Yes	4.9
A.6.10 Emissions, production and/or use of hazardous substances (e.g. gases, liquids, dusts, mists, vapour)	No	
A.6.11 Unattended operation	Yes	Annex A
A.6.12 Connection to and interruption from power supply	Yes	4.2, 4.3, 4.4.4.4, 4.4.8, 4.8, 4.11
A.6.13 Combination of equipment	Yes	4.1, 4.2, 4.4.2.3
A.6.14 Implosion	No	
A.6.15 Hygiene conditions	No	
A.6.16 Ergonomics	No	
A.7 Functional safety and reliability	No	
A.7.2 Equipment design	No	
A.7.3 Type related hazards	No	
A.7.4 *System* faults	No	
A.8 Safety-related security	No	
Allocate the requirements 1) to 3) to the categories a) to d) taking into account the foundational requirements I. to V.	No	
a) Protection against casual or coincidental violation	No	
b) Protection against intentional violation using simple means with low resources, generic skills and low motivation	No	
c) Protection against intentional violation using sophisticated means with moderate resources, specific skills related to the considered equipment and moderate motivation	No	
d) Protection against intentional violation using sophisticated means with extended resources, specific skills related to the considered equipment and high motivation	No	
A.9 Information requirements	Yes	6.1 to Annex A
NOTE This table is derivied from IEC Guide 116:2018, Table D.1.		

Annex S
(informative)

In-some-country requirements – United States of America voltages less than 1,5 kV AC or DC

S.0 General

The following clauses are applicable to *BDM/CDM/PDS* intended for installation in the United States of America (USA). These requirements either add to, modify, replace, or delete (make not applicable) the requirements found in the main part of this document. Unless stated otherwise, these requirements are in addition to the original requirement of this document. Requirements from the main part of this document otherwise not referenced in Annex S are applicable as they are written. The current and complete list of US national differences is published in the most recent edition and revision of UL 61800-5-1.

The clauses in Annex S follow the numbering of those in the main part of the document. The main structure of this document is mirrored in this Annex S as headlines inserted as active links to give an easy possibility to jump to the applicable IEC text. Any additional numbered items are numbered starting from 200.

NOTE US national differences in Annex S are included with permission from UL and are based on UL 61800-5-1, 1st ed., revision February 24, 2017, and in some cases revised due to changes to normative requirements from IEC 61800-5-1:2007 to this document.

S.1 Scope

Addition to Clause 1:

The scope is limited to adjustable speed electrical power drive systems intended to feed a motor or motors from a *BDM* connected to phase-to-phase voltages up to and including 1,5 kV AC 50 Hz or 60 Hz and/or voltages up to and including 1,5 kV DC.

The scope is limited to *BDM/CDM/PDS* to be installed in ordinary locations in accordance with Articles 430 and 440 of the US National Electrical Code, ANSI/NFPA 70.

A *component* of a product covered by this document must comply with the requirements for that *component*. See Clause S.201 for a list of additional standards covering *components* used in the products covered by this document.

This document is only applicable to the power conversion and *BDM/CDM* control equipment, servo *BDM/CDM* and integral servo *BDM/CDM* /motor combinations.

S.2 Normative references

Addition to Clause 2:

See Clause S.201 for USA normative references and *component* standards. See Clause S.202 for IEC normative references that do not apply and for IEC normative references replaced by USA standards.

S.3 Terms and definitions

The following are additional terms and definitions that are applicable in the USA or addition to existing terms as applicable in the USA.

S.3.46
low-voltage

Addition:

Note to entry: *BDM/CDM/PDS* operating at more than 600 V AC is considered *high-voltage BDM/CDM/PDS* with respect to the requirements in the US National Electrical Code, ANSI/NFPA 70.

S.3.47
low-voltage BDM/CDM/PDS

Addition:

Note to entry: *BDM/CDM/PDS* operating at more than 600 V AC is not considered *low-voltage BDM/CDM/PDS* with respect to the requirements in the US National Electrical Code, ANSI/NFPA 70.

Additional terms and defintions:

S.3.200
group installation
motor branch-circuit for two or more motors, or one or more motors with other loads and protected by a circuit breaker or a single set of fuses

S.3.201
insulated live part
electrically live part that is provided with complete protection against electric shock and does not rely upon other parts for insulation

S.4 Protection against hazards

S.4.1 General

Addition to 4.1:

BDM/CDM must be so constructed that it complies with the rules for installation and use of such equipment as given in the US National Electrical Code, ANSI/NFPA 70.

For isolated secondary circuits, the requirements in S.203.1 can be used to determine if any of the requirements for risk of electric shock, thermal or energy hazards may be omitted.

S.4.2 *Single-fault conditions* and *abnormal operating condition*

Addition to 4.2:

Analysis must include class 2, limited voltage/current secondary, or limiting impedance circuits as defined in S.203.1 only where a failure of the a *component* in the circuit creates a hazard in a circuit that is not sourced from the isolated secondary circuit.

S.4.3 Short-circuit and overload protection

S.4.3.1 General

Addition to 4.3.1:

The number, arrangement, and ratings or settings of protective devices intended to provide motor branch-circuit short-circuit and ground-fault protection must be as required by Part IV, Article 430 of the US National Electrical Code, ANSI/NFPA 70.

IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017, 411.3.2, and IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017, 415.2, are not applicable in the USA.

S.4.3.2 Input short-circuit rating and available *output short-circuit current*

S.4.3.2.1 General

S.4.3.2.2 Rated *conditional short-circuit current* (I_{cc}) on input power *ports*

Addition to 4.3.2.2:

For co-ordination with upstream protective devices, the manufacturer must specify a maximum *prospective short-circuit current* rating. The *prospective short-circuit current* rating must be no less than the current specified in Table 36 based on the full load current output rating of the *BDM/CDM*. For a *BDM/CDM* rated only in horsepower and not in current, the equivalent horsepower rating must be as specified in Table S.29 and Clause S.204.

A *BDM/CDM* series must comply with the short-circuit test – high fault currents, S.5.2.4.2.202, and the short-circuit test – standard fault currents, 5.2.4.5, when it is intended to be rated with

a) a standard fault current value in accordance with Table 36, and
b) a high fault current value in excess of the standard fault current value.

A *BDM/CDM* series is in compliance with the short-circuit test – high fault currents, S.5.2.4.2.202, without additional testing when

c) the *BDM/CDM* series uses *electronic power output short-circuit protection circuitry* for compliance with the standard fault current short-circuit test, and
d) the *electronic power output short-circuit protection circuitry* is used in accordance with e) to k) below.

Any model can serve as the representative model from a series that uses *electronic power output short-circuit protection circuitry* for compliance with this test. As an example, for a *BDM/CDM* series with models rated from 25 hp to 700 hp (18,64 kW to 521,99 kW), the testing of the 25 hp model at 5 000 A represents the testing of any models at 10 000 A, 18 000 A, 30 000 A or 42 000 A. In addition, short-circuit testing may be conducted at 5 000 A to represent higher short-circuit test values when all of the following requirements are met.

e) The same solid state protection circuitry is used throughout the series.
f) Any revisions to the protection circuitry requires re-evaluation.
g) The protection circuitry turns off the output devices (insulated gate bi-polar transistor – IGBT), bi-polar, and similar devices prior to the time in which the devices are damaged by any increase in current. This is based on the manufacturer's rating of the output devices (typically 10 µs for IGBTs, and 50 µs for bi-polars).
h) Any increase in current experienced by the output devices is the result of the DC bus capacitor bank discharging.
i) The output devices are turned off by the protection circuitry prior to any significant increase in the input current.
j) In response to a higher standard fault current (for example 42 000 A vs. 5 000 A), the protection circuitry must react to the higher standard fault current (42 000 A) in the same or shorter time as the lower standard fault current (5 000 A). This may be verified through testing at the higher fault current value or through visual inspection in 5.2.1 of the electronic power output short-circuit protection circuitry hardware and software.

k) When relying on current sensing (as opposed to output device collector voltage sensing) to actuate the protection circuitry, either the DC bus or all main motor output lines must be monitored.

A *BDM/CDM* that does not rely solely on solid-state short-circuit protection must also comply with the short-circuit test power factor requirements in UL 60947-4-1.

S.4.3.3 Short-circuit coordination (upstream protection)

Addition to 4.3.3:

See S.4.3.2.1 for more information on short-circuit coordination.

S.4.3.4 Protection by several devices

S.4.3.5 Motor overload and overtemperature protection

S.4.3.5.1 Means of protection

Addition to 4.3.5.1:

The number, arrangement, and ratings or settings of protective devices intended to provide motor and branch-circuit overload protection must be as required by Part III, Article 430 of the US National Electrical Code, ANSI/NFPA 70.

S.4.3.5.2 *BDM/CDM* with *electronic motor overload protection*

Addition to 4.3.5.2:

Adjustable *electronic motor overload protection* may be adjustable in such a way that the limit of 1,2 times the current setting with a tripping time of 2 h of Table 37 is exceeded; however, 1,25 times the current setting with a tripping time of 2 h must not be exceeded.

S.4.4 Protection against electric shock

S.4.4.1 General

S.4.4.2 *Decisive voltage class (DVC)*

S.4.4.3 Provision for *basic protection*

S.4.4.3.1 General

S.4.4.3.2 Protection by means of *basic insulation* of *hazardous live parts*

S.4.4.3.3 Protection by means of *enclosures* or barriers

Replacement of 4.4.3.3:

Accessibility of *live parts* of *DVC B* or *DVC C* circuits, excluding isolated secondary circuits of *DVC B* that have been investigated to S.203 which do not require protection against direct contact as indicated by Table S.28, must be determined in accordance with mechanical requirements for enclosures in S.4.12.

S.4.4.4 Provision for *fault protection*

S.4.4.4.1 General

S.4.4.4.2 *Protective equipotential bonding*

S.4.4.4.2.1 General

Modification to 4.4.4.2.1:

Item b) of 4.4.4.2.1 is not applicable.

Additional subclause to 4.4.4.2:

S.4.4.4.2.200 Bonding

Other than as noted in the following paragraph, an *enclosure* made of insulating material, either wholly or in part, must have bonding means to provide continuity of grounding between all conduit openings. The bonding means must be either completely assembled on the product or provided as separate parts for field installation.

A bonding means is not required for an *enclosure* that is intended to be connected to a single conduit. *Enclosures* must be marked in accordance with S.6.3.9.200.

A bonding means is not required to be provided with each *enclosure* when such means is available in the form of a kit from the manufacturer and the *BDM/CDM/PDS* complies with the marking requirements in S.6.3.9.200.

Other than as noted in the following paragraph, the continuity of a conduit *system* must be provided by metal-to-metal contact not relying on a polymeric material.

The continuity of the grounding *system* is not prohibited from relying on the integrity of the polymeric *enclosure* when samples have been subjected to the creep test requirements in UL 746C. Overcurrent tests must be conducted at 200 % of the rated current of the branch-circuit-protective device.

A separate bonding conductor whether in a plastic or metal *enclosure* must be copper, a copper alloy, or other material determined to be usable as an electrical conductor. Ferrous metal parts in the grounding path must be protected against corrosion by enameling, galvanizing, plating, or other equivalent means. A separate bonding conductor must

a) be protected from mechanical damage or be located within the confines of the outer *enclosure* or frame, and
b) not be secured by a removable fastener used for any purpose other than bonding unless the bonding conductor is unable to be omitted after removal and replacement of the fastener.

Other than as noted in in the following paragraph, the size of a separate *component* bonding conductor must not be less than the applicable size specified in Table S.1 or the size of the conductor supplying the *component*, whichever is smaller.

A bonding conductor is not required to be as large as specified in the previous paragraph when

c) it does not open when carrying, for the time specified in Table S.2, a current equal to twice the branch-circuit overcurrent-device rating (see S.4.4.4.2.200) and not less than 40 A, and
d) none of three samples of the bonding conductor opens during a limited-short-circuit test with a current as specified in Table S.3 when in series with a fuse as described in the following paragraph.

Table S.1 – Size of bonding conductor

Maximum rating or setting of automatic *overcurrent* device in circuit ahead of *BDM/CDM/PDS* A	Minimum size of bonding conductor[a]			
	Copper wire AWG (mm²)		Aluminum wire AWG or kcmil (mm²)	
15	14	(2,1)	12	(3,3)
20	12	(3,3)	10	(5,3)
30	10	(5,3)	8	(8,4)
40	10	(5,3)	8	(8,4)
60	10	(5,3)	8	(8,4)
100	8	(8,4)	6	(13,3)
200	6	(13,3)	4	(21,2)
300	4	(21,2)	2	(33,6)
400	3	(26,7)	1	(42,4)
500	2	(33,6)	1/0	(53,5)
600	1	(42,2)	2/0	(67,4)
800	1/0	(53,5)	3/0	(85,0)
1 000	2/0	(67,4)	4/0	(107,0)
1 200	3/0	(85,0)	250	(127,0)

[a] Or equivalent cross-sectional area.

Table S.2 – Duration of current flow for bonding-conductor test

Overcurrent device rating A	Minimum duration of current flow Min
30 or less	1
31 to 60	4
61 to 100	6

Table S.3 – Bonding conductor short-circuit test capacity

Controller rating			
hp	(kW output)	V	Circuit capacity A
1/2	(0,373)	0 to 250	200
1/2	(0,373)	251 to 600	1 000
Over 1/2 to 1	(0,374 to 0,746)	0 to 600	1 000
1 to 3	(0,747 to 2,24)	0 to 250	2 000
Over 3 to 7-1/2	(2,25 to 5,59)	0 to 250	3 500
Over 7-1/2 to 10	(5,60 to 7,46)	0 to 250	5 000
Over 10 to 50	(7,47 to 37,3)	251 to 600	5 000
Over 50 to 200	(37,4 to 149)	0 to 600	10 000
Over 200	(over 150)	0 to 600	[a]

[a] See Table 36.

The circuit for the test required by the previous paragraph is to have a power factor of 0,9 to 1,0 and is to be limited to the current specified in Table S.3. The open-circuit voltage of the test circuit is to be 100 % to 105 % of the specified voltage. The circuit is to be connected through a nonrenewable fuse that conducts twice its rated current for at least 12 s. The fuse rating is to be that of the branch-circuit *overcurrent* device to which the *BDM/CDM/PDS* is intended to be connected and not less than 20 A. One test is to be performed on each of three samples of the bonding conductor.

S.4.4.4.3 *PE conductor*

S.4.4.4.3.1 General

Addition to 4.4.4.3.1:

The *PE conductor* must be sized as specified in Article 250.122 and Table 250.122 of the US National Electrical Code, ANSI/NFPA 70.

For the internal grounding and bonding conductor colour, see 4.11.5.

S.4.4.4.3.2 Means of connection for the *PE conductor*

Addition to 4.4.4.3.2:

*Port*able *BDM/CDM/PDS* must be provided with a power-supply cord with a grounding conductor. The grounding conductor must be connected to the grounding blade of a grounding attachment plug and must be connected to the frame or *enclosure* of the *BDM/CDM/PDS*. The surface of the *insulation* on the grounding conductor must be green with or without one or more yellow stripes.

When the grounding means is not provided on the *BDM/CDM/PDS* as shipped, the *BDM/CDM/PDS* must be marked in accordance with 6.3.7.5.

S.4.4.4.3.3 *Touch current* in case of failure of *PE conductor*

Addition to 4.4.4.3.3:

In the US, *pluggable equipment type B* is pluggable *BDM/CDM/PDS* incorporating a plug or connector complying with UL 498. *Pluggable equipment type A* is *BDM/CDM/PDS* incorporating a plug or connector compliant with any other appropriate standard for plugs or connectors.

S.4.4.5 Provisions for *enhanced protection*

S.4.4.6 Protective measures

Additional subclauses to 4.4.6:

S.4.4.6.200 *Control circuit* transformer earthing

Where the secondary of a *control circuit* transformer is intended to supply an external circuit, the secondary must be connected to *protective earthing* under any of the following:

a) if the transformer primary voltage exceeds 150 V to earth, and the secondary voltage is 50 V or less;
b) if the secondary voltage is 50 V to 1 000 V, and the secondary can be connected to *protective earthing* such that the maximum voltage to ground for the ungrounded conductors does not exceed 150 V.

S.4.4.6.201 Transformers

S.4.4.6.201.1 *Control circuit* transformer protection

Other than as noted in the following paragraph, a transformer whose secondary supplies a circuit incorporating the coil of an internal or external motor control contactor (such as for soft starting) must be provided with additional protection. The protection must either be a supplementary or a branch-circuit type fuse or circuit breaker in accordance with the UL 248 series or UL 489, respectively and must

a) for the primary:
   1) be provided in each ungrounded conductor of the transformer primary and rated or set in accordance with Table S.4; and either,
   2) be provided in the transformer primary and rated or set at a maximum of 6 times the rated transformer primary current when the transformer has no more than 6 % impedance and coordinated thermal overload protection is arranged to interrupt the primary circuit; or
   3) be provided in the transformer primary and rated or set at a maximum of 4 times the rated transformer primary current when the transformer has more than 6 % and less than 10 % impedance and coordinated thermal overload protection is arranged to interrupt the primary circuit;

b) for the primary and secondary:
   4) be provided in the transformer primary and rated or set at not more than 250 % of the rated transformer primary current and provided in the transformer secondary and rated or set at not more than 125 % of the rated transformer secondary current; or
   5) be provided in the transformer primary and rated or set at not more than 250 % of the rated transformer primary current and provided in the transformer secondary and rated or set in accordance with row 2 of Table S.4 when the rated transformer secondary current is 2 A or more.

A transformer is not required to be additionally protected when any of the following conditions exist:

a) the transformer secondary supplies a class 1 power-limited or class 3 remote-*control circuit* or supplies a class 2 (see S.203.1.5), limited voltage/current (see S.203.1.6), limited energy (see S.203.1.7) or limiting impedance (see S.203.1.8) secondary circuit;
b) the transformer secondary is rated less than 50 VA, is inherently protected and is an integral part of the *BDM/CDM*;
c) the branch-circuit protection provides the required additional protection; or,
d) the additional protection is provided by other means that comply with the applicable requirements in the US National Electrical Code, ANSI/NFPA 70.

Table S.4 – Maximum rating of *overcurrent* device

Primary current rating A	Maximum rating of *overcurrent* protective device expressed as a percent of transformer primary current rating
Less than 2	500
2 to less than 9	167
9 or more	125 [a]

[a] When 125 % of the current does not correspond to a standard fuse or nonadjustable circuit breaker rating, then the next higher standard rating must be used. See Section 240-6 of the US National Electrical Code, ANSI/NFPA 70.

S.4.4.6.201.2 *Control circuit* wiring and transformer combination

For a single phase transformer with only one 2-wire secondary, compliance with the additional wiring and transformer protection requirements of S.4.11.200.1 and S.4.4.6.201.1 is obtainable by protective devices in any ungrounded primary conductor. The protective devices must

a) be located in the primary of the transformer,

b) have its maximum rating or setting limit calculated by using the appropriate protective device value from Table S.12 based on the AWG of the secondary wiring and multiplying this value by the secondary-to-primary voltage ratio of the transformer, and

c) have its actual rating or setting be within this maximum limit and also be in accordance with S.4.4.6.201.2 a) and b).

S.4.4.6.201.3 Performance

Other than as noted in the following paragraph, a transformer employed in *BDM/CDM/PDS* must comply with the appropriate standard for transformers, unless the load is part of the *BDM/CDM/PDS*, in which case the transformer must comply with the temperature test, 5.2.3.10, and the AC or DC voltage test, 5.2.3.4.

Pulse and current transformers constructed in a manner other than required by the applicable UL transformer standard are in compliance with the requirement of the previous paragraph when they withstand, without breakdown, a dielectric voltage withstand potential in accordance with the AC or DC voltage test, 5.2.3.4, applied between the primary and secondary windings. An example of transformer constructions for which this applies are those that rely upon magnet wire coating to provide isolation instead of interwinding tape.

S.4.4.7 *Insulation*

S.4.4.7.1 Influencing factors

S.4.4.7.1.1 General

Addition to 4.4.7.1.1:

Field wiring terminals that do not preclude the possibility of stray strands must comply with the *clearance* and *creepage distances* requirements of S.200.1.

For an *enclosure* without conduit openings or knockouts, *clearance* and *creepage distances* not less than the minimum specified in S.200.1 must be provided between un*insulated live parts* and a conduit bushing installed at any location to be used during installation. A permanent marking on the *enclosure*, a template, or a full-scale drawing furnished with the *BDM/CDM/PDS* is usable to identify such locations. For measurement of *clearance* and *creepage distances*, it is to be assumed that a bushing having the dimensions specified in Table S.5 is in place, in conjunction with a single locknut installed on the outside of the *enclosure*.

Table S.5 – Dimensions of bushings

Trade size of conduit in	Bushing dimensions in (mm)			
	Maximum overall diameter		Height	
1/2	1	(25,4)	3/8	(9,5)
3/4	1-15/64	(31,4)	27/64	(10,7)
1	1-19/32	(40,5)	33/64	(13,1)
1-1/4	1-15/16	(49,2)	9/16	(14,3)
1-1/2	2-13/64	(56,0)	19/32	(15,1)
2	2-45/64	(68,7)	5/8	(15,9)
2-1/2	3-7/32	(81,8)	3/4	(19,1)
3	3-7/8	(98,4)	13/16	(20,6)
3-1/2	4-7/16	(113)	15/16	(23,8)
4	4-31/32	(126)	1	(25,4)
5	6-7/32	(158)	1-3/16	(30,2)
6	7-7/32	(183)	1-1/4	(31,8)

For clamped insulating joints, *clearance* and *creepage distances* must be measured through cracks illustrated in Figure S.5 unless the clamped joint complies with the requirements of S.200.

Clearance and *creepage distances* on the supply side of branch-circuit protective devices in *BDM/CDM/PDS* rated 600 V or less and intended for installation in a feeder circuit must comply with Table S.6.

Table S.6 – *BDM/CDM/PDS* intended for installation in a feeder circuit

Voltage between parts involved	Minimum *clearance*s and *creepage distance*s in inches (mm)							
	Between uninsulated parts of opposite polarity on supply side				Between uninsulated parts on supply side and any grounded dead metal			
	Creepage distance		*Clearance*		*Creepage distance*		*Clearance*	
0 to 125	3/4	(19,1)	1/2	(12,7)	1/2	(12,7)	1/2	(12,7)
126 to 250	1-1/4	(31,8)	3/4	(19,1)	1/2	(12,7)	1/2	(12,7)
251 to 600	2	(50,8)	1	(25,4)	1	(25,4)	1	(25,4)

S.4.4.7.1.2 *Working voltage*

S.4.4.7.1.3 Pollution degree

Addition to 4.4.7.1.3:

The motor *insulation system* must meet the requirements of the UL 1004 series.

Pollution degree 1 is obtainable by the encapsulation or hermetic sealing of the product. Typical constructions that meet this requirement are:

a) the use of conformal coating on printed wiring board foil traces that complies with the requirements for conformal coatings in the standard for polymeric materials – electrical equipment evaluations, UL 746C;
b) the use of any potting material or encapsulation, such as epoxy;

c) the use of silicone rubber at a thickness of at least 1/32 in (0,8 mm);

d) the use of a case or *enclosure* that is hermetically sealed against the entrance of an external atmosphere by means of fusion – such as from soldering, brazing, welding, or the fusion of glass to metal.

Pollution degree 2 is obtainable by reducing possibilities of conductive pollution and reducing possibilities of condensation or high humidity at the *creepage distance*s.

e) Typical constructions that reduce the possibility of conductive pollution are
   1) the use of an un-ventilated *enclosure*, or
   2) the use of a ventilated *enclosure* when all ventilation openings are filtered.

f) Typical constructions that reduce the effects of condensation or high humidity are
   1) the use of a ventilated *enclosure*,
   2) the continuous application of heat through the use of heaters,
   3) the application of heat through continuous energization of the *BDM/CDM/PDS*, with interruptions such that cooling to the point of condensation does not occur, or
   4) the use of any coatings, such as solder masking, on printed wiring board foil traces.

S.4.4.7.2 *Insulation* to the *surroundings*

S.4.4.7.2.1 General

S.4.4.7.2.2 *SPD* monitoring

S.4.4.7.2.3 Circuits connected directly to *mains supply*

Addition to 4.4.7.2.3:

PDS must be evaluated at least as overvoltage category III.

S.4.4.7.2.4 Circuits connected to *non-mains supply*

S.4.4.7.2.5 *Insulation* between circuits

Addition to 4.4.7.2.5:

In the *field wiring* area, provisions for wiring for class 2 and class 3 circuits must meet the requirements for separation from class 1 circuits in accordance with Section 725 of the US National Electrical Code, ANSI/NFPA 70. See also S.203.1.1.

S.4.4.7.3 *Functional insulation*

S.4.4.7.4 *Clearance*

S.4.4.7.5 *Creepage distances*

S.4.4.7.6 Coating or potting

Addition to 4.4.7.6:

Clearance and *creepage distance*s required to be greater than 1/32 in (0,8 mm) may be reduced to 1/32 in (0,8 mm) on a printed wiring board when the printed wiring board *clearance* and *creepage distances* are

a) covered by a layer of silicone rubber at least a 1/32 in (0,8 mm) thick, or

b) encapsulated by epoxy or potting material, without air bubbles. The silicone rubber and the potting material, when used, must comply with UL 94, UL 746B, or UL 746C.

S.4.4.7.7 *Clearance* and *creepage distances* for *functional insulation* on PWB and *components* assembled on PWB

S.4.4.7.8 Solid insulation

S.4.4.7.8.1 General

S.4.4.7.8.2 Material requirements

Addition to 4.4.7.8.2:

Except as noted in the following paragraphs, an insulating material must

a) comply with 4.4.7.8.2, and
b) be at least 0,028 in (0,71 mm) thick.

These two requirements are independent of each other. For example, even when a material complies with 4.4.7.8.2 at a thickness less than the 0,028 in (0,71 mm) limit, then the material still is required to be provided at a thickness at least equal to this 0,028 in (0,71 mm) limit or at a thickness as specified by the following two paragraphs

A material that complies with 4.4.7.8.2 and does not comply with the thickness limit in b) can alternatively be subjected to a 5 000 V AC dielectric voltage withstand test in accordance with the internal barrier requirements in UL 746C.

A material that complies with 4.4.7.8.2 and is used in addition to not less than one-half the required through air *clearance* and *creepage distances* can be less than 0,028 in (0,71 mm) thick, and must be at least 0,013 in (0,33 mm) thick. This material must

a) have the required mechanical strength when exposed or otherwise subjected to mechanical damage,
b) be held in place, and
c) be so located that it is not adversely affected by operation of the *BDM/CDM/PDS* in service.

No further evaluation is required when generic materials of Table S.7 are used at a distance greater than those of Table 12, are used within the minimum thickness of Table S.7, and the measured temperature during the temperature rise test does not exceed the temperature limits of Table S.7.

Table S.7 – *Generic materials for barriers*

Generic material	Minimum thickness mm	Maximum temperature °C
Aramid paper	0,25	105
Cambric	0,71	105
Electric grade paper	0,71	105
Epoxy	0,71	105
Mica	0,71	105
Mylar (PET)	0,71	105
RTV	0,71	105
Silicone	0,71	105
Treated cloth	0,71	105
Vulcanized fiber	0,71	105

Additional subclause to 4.4.7:

S.4.4.7.200 Isolation devices

Optical isolators that provide isolation between primary and secondary circuits must be constructed in accordance with UL 1577, except as noted in the following paragraph. The rated isolation voltage of the optical isolator must be at least the minimum dielectric voltage withstand rating test voltage required by 5.2.3.4, AC or DC voltage test. Alternately, an optical isolator that is constructed in accordance with the requirements in UL 1577, and rated at a dielectric potential less than that required by the AC or DC voltage test, 5.2.3.4, complies with with this clause when the internal *insulation* is at such thickness that it also complies with 0,71 mm minimum.

An optical isolator is not required to be subjected to the requirements in the standard for optical isolators, UL 1577, when the internal *insulation* is of such a material and at such a thickness that it complies with S.4.4.7.8.2.

Power switching semiconductor devices that provide isolation to ground must be constructed in accordance with UL 1557, except as noted in the following paragraph. The dielectric voltage withstand tests required by UL 1557 must be conducted at a dielectric potential in accordance with the AC or DC voltage test, 5.2.3.4. Alternately, a power switching semiconductor that is constructed in accordance with UL 1557 and rated at a dielectric potential less than that required by the AC or DC voltage test, 5.2.3.4, complies with this paragraph when the internal *insulation* is at least 0,71 mm thick.

A power switching semiconductor is not required to be subjected to the requirements in UL 1557 when the internal *insulation* is of such material and at such a thickness that it complies with 0,71 mm minimum.

Additional subclauses to 4.4:

S.4.4.200 Blower motors

Other than blower motors located in a class 2 (see S.203.1.5), limited voltage/current (see S.203.1.6) or limiting impedance (see S.203.1.7) secondary circuit, each blower motor must be provided with

a) locked rotor protection in accordance with the following paragraph, and
b) an *enclosure* in accordance with *enclosures*, S.4.12.

The locked rotor protection required by part a) of the preceding paragraph must

c) comply with the thermal protection requirements in UL 2111, or,
d) comply with the impedance protection requirements in UL 2111, or,
e) involve an alternative protection means that is shown by test to be equivalent to the protection specified in c).

Regarding part e) above, an example of an alternative protection means is the use of fusing to limit the locked rotor temperature of the blower motor windings in accordance with the thermal protection requirements in UL 2111. The fusing in this example must be branch-circuit or supplementary types in accordance with the UL 248 series.

S.4.4.201 Fuseholders

Other than as noted in the following two paragraphs, *BDM/CDM* incorporating a disconnect switch and a fuseholder must be so constructed that when the switch contacts are open, the fuse may be replaced without touching any energized part.

A control-circuit fuse arrangement is not required to comply with this requirement when the fuse and control-circuit load – other than a fixed control-circuit load, such as a pilot lamp – are within the same *enclosure*.

This requirement is not applicable to fuses that are non-accessible and are not for renewal. Fuses are considered non-accessible when destruction or damage to the *enclosure* or some portion of the assembly containing the fuseholder is required to contact *live parts*.

S.4.5 Protection against electrical energy hazards

S.4.6 Protection against fire and thermal hazards

S.4.6.1 General

S.4.6.2 Circuits and *components* representing a fire hazard

Addition to 4.6.2:

A contactor in a power circuit must be suitable for controlling the connected load, including making, carrying and breaking the overload current that can be delivered by the *BDM/CDM/PDS*. A contactor with lower ratings may be used when it is interlocked or sequenced such that under normal operating conditions the contactor does not make or break load current and meets the requirements of S.5.2.4.200.

S.4.6.3 Selection of *components* to mitigate the risk of a fire hazard

S.4.6.4 Fire protection provided by *enclosures*

Replacement of 4.6.4:

See S.4.12 for requirements for *enclosures* in the USA.

Additional subclause to 4.6:

S.4.6.200 *BDM/CDM* for use in air handling spaces (plenums)

BDM/CDM intended for use in air handling ducts and plenums must be of the enclosed type and must comply with all other applicable requirements of this document.

BDM/CDM with *enclosures* that are either whole or in part non-metallic and intended to be installed in air-handling spaces must additionally comply with the requirements in UL 2043.

The requirements in the preceding paragraph do not apply to the following:

a) air filters, *BDM/CDM* belts, wire *insulation*, paint applied for corrosion protection, or tubing of material equivalent to one of the types of wire *insulation* permitted by this document;
b) gaskets forming air or water seals between metal parts;
c) miscellaneous small parts such as refrigerant line bushings or insulating bushings, resilient or vibration mounts, wire ties, clamps, labels, or drain line fittings having a total exposed surface area not exceeding 25 square inches (161,29 cm^2);
d) an adhesive that, when tested in combination with the specific insulating material, complies with the requirement.

Metallic *enclosure* surfaces, including those which are ventilated, are suitable for use in air handling ducts and plenums without further investigation.

S.4.7 Protection against mechanical hazards

S.4.7.1 General

S.4.7.2 Critical torsional speed

S.4.7.3 Transient torque analysis

S.4.7.4 Specific requirements for liquid cooled *BDM/CDM/PDS*

S.4.7.4.1 General

S.4.7.4.2 Coolant

Addition to 4.7.4.2:

The specified coolant (see 6.2) must be suitable for an anticipated *ambient temperature* of 0 °C to 40 °C (32°F to 104 °F) unless rated and marked for a different temperature range.

S.4.7.4.3 Design requirements

S.4.7.4.3.1 General

S.4.7.4.3.2 Corrosion resistance

S.4.7.4.3.3 Tubing, joints and seals

Addition to 4.7.4.3.3:

Tubing used to connect refrigerant-containing *components* must comply with the minimum wall thickness requirements of Table S.8 and with the hydrostatic pressure test requirements of 5.2.7.

Table S.8 – Tubing wall thickness

Outside diameter		Minimum wall thicknes[a] in (mm)					
		Copper				Steel	
in	(mm)	Protected		Unprotected			
3/16	(4,76)	0,024 5	(0,62)	0,026 5	(0,67)	0,025	(0,64)
1/4	(6,35)	0,024 5	(0,62)	0,026 5	(0,67)	0,025	(0,64)
5/16	(7,94)	0,024 5	(0,62)	0,028 5	(0,72)	0,025	(0,64)
3/8	(9,53)	0,024 5	(0,62)	0,028 5	(0,72)	0,025	(0,64)
1/2	(12,70)	0,024 5	(0,62)	0,028 5	(0,72)	0,025	(0,64)
5/8	(15,88)	0,031 5	(0,80)	0,031 5	(0,80)	0,032	(0,81)
3/4	(19,05)	0,031 5	(0,80)	0.038 5	(0,98)	0,032	(0,81)
7/8	(22,23)	0,041 0	(1,04)	0,041 0	(1,04)	0,046	(1,17)
1	(25,40)	0,046 0	(1,17)	0,046 0	(1,17)	0,046	(1,17)
1-1/8	(28,58)	0,046 0	(1,17)	0,046 0	(1,17)	0,046	(1,17)
1-1/4	(31,75)	0,050 5	(1,28)	0,050 5	(1,28)	0,046	(1,17)
1-3/8	(34,93)	0,050 5	(1,28)	0,050 5	(1,28)	0,046	(1,17)
1-1/2	(38,10)	0,055 5	(1,41)	0,055 5	(1,41)	0,062	(1,58)
1-5/8	(41,3)	0,055 5	(1,410)	0,055 5	(1,410)	-	-
2-1/8	(54,0)	0,064 0	(1,626)	0,064 0	(1,626)	-	-
2-5/8	(66,7)	0,074 0	(1,880)	0,074 0	(1,880)	-	-

NOTE "Protected" implies that the tubing is shielded by the cabinet or assembly, to the extent that unintended damage caused by objects such as tools falling on or otherwise striking the tubing during handling and after installation of the unit is prevented. This protection may be provided in the form of baffles, channels, flanges, perforated metal, or equivalent means. If a cabinet is employed for the intended installation of a unit, the tubing is considered shielded. Tubing not so shielded is considered to be unprotected.

[a] Nominal wall thickness of tubing will have to be greater than the thickness indicated to maintain the minimum wall thickness.

S.4.7.4.3.4 Provision for condensation

S.4.7.4.3.5 Conductivity of coolant

S.4.7.4.3.6 Leakage of coolant

Addition to 4.7.4.3.6:

When provided, a pressure relief mechanism must comply with the hydrostatic pressure test (see 5.2.7). Coolant released as the result of operation of a pressure relief mechanism must not be released into any electrical compartment.

Additional subclause to 4.7:

S.4.7.200 Phase reversal protection

BDM/CDM/PDS provided with phase reversal protection must interrupt and maintain the interruption of power in all of the motor circuit.

S.4.8 *BDM/CDM/PDS* with multiple sources of supply

S.4.9 Protection against environmental stresses

Addition to 4.9:

Humidity, vibration, and UV resistance are not required to be declared. *Ambient temperature*, if applicable, is only required if other than 40 °C. *Surrounding air temperature* rating is required if applicable. Pollution degree is only required if the *BDM/CDM/PDS* is only suitable for use in a pollution degree 2 environment.

S.4.10 Protection against excessive acoustic noise hazards

S.4.11 Wiring and connections

S.4.11.1 General

S.4.11.2 *Insulation* of conductors

Addition to 4.11.2:

Wiring that is subject to flexing during servicing, such as that from a stationary part to a part mounted on a hinged *door* or other movable part, must be provided with *insulation* not less than 1/32 in (0,8 mm) thick. The wiring must be flexible cord or must comply with either of the following.

a) Wiring other than flexible cord may be used when provided with additional *insulation* at any point where it is flexed. This additional *insulation* must be insulating sleeving, tubing, or a wrapping of not less than two layers of insulating tape. The *insulation* must be made of materials rated for the temperature and voltage involved.

b) Wiring other than flexible cord may be used without additional *insulation* when damage to the wiring is not evident and the wiring withstands the AC or DC voltage test, 5.2.3.4 applied between conductors and between conductors and ground, after the wiring is mounted as intended and tested by opening the *door* or other movable part as far as possible and then returning it to the original position for 500 cycles of operation (restraints such as a chain are to remain in place).

S.4.11.3 Stranded wire

Addition to 4.11.3:

Field wiring terminals are not required to preclude the possibility of stray strands if the *clearance* and *creepage distances* of the *field wiring terminals* comply with S.200.1.

Means for internal wiring connected to a wire-binding screw that prevent loose strands from contacting parts as indicated in the second paragraph of 4.11.3 include machine- or tool-applied pressure terminal connectors, soldering lugs, crimped eyelets, or the soldering of all strands of the wire together.

S.4.11.4 Routing and clamping

S.4.11.5 Identification of conductors and terminals of *mains supply* and *non-mains supply*

Replacement of 4.11.5:

Insulated grounding and bonding conductors smaller than 4 AWG must be identified by the colour green with or without one or more yellow stripes throughout the entire product. Insulated conductors sized 4 AWG or larger must be identified in this manner, or must be identified at each termination point by a green marking, such as green tape wrapped around the conductor. No other leads must be so identified. This requirement does not apply to a green or green/yellow conductor provided in a wiring harness, ribbon cable, or similar prefabricated wiring assembly, which is not likely to be mistaken for a grounding conductor.

S.4.11.6 Splices and connections

Addition to 4.11.6:

A splice must be provided with *insulation* equivalent to that of the wires involved.

The *insulation* must be made of materials rated for the temperature and voltage involved. In determining when splice *insulation* consisting of coated-fabric, thermoplastic, or other types of tubing is usable, electrical and mechanical properties including dielectric voltage-withstand ability, heat resistance, and moisture resistance must be evaluated. For requirements of additional *insulation*, the following paragraph applies. Thermoplastic tape must not be wrapped over a sharp edge or connection.

Additional *insulation*, when used, must be insulating sleeving, tubing, or a wrapping of not less than two layers of insulating tape. The *insulation* must be made of materials rated for the temperature and voltage involved.

S.4.11.7 Accessible connections

S.4.11.8 Interconnections between parts of the *PDS*

S.4.11.9 Supply connections for *permanently connected BDM/CDM/PDS*

Replacement of 4.11.9:

The *BDM/CDM/PDS* must be so constructed that the *installation* can comply with requirements as specified in Article 310 and Tables 310-16 or 310-17, as appropriate, of the US National Electrical Code, ANSI/NFPA 70.

BDM/CDM/PDS intended to be *permanently connected* to the power supply must have provision for connection of one of the applicable wiring *system*s in accordance with the US National Electrical Code, ANSI/NFPA 70, unless it is intended to be drilled or punched in the field to accommodate a wiring *system* and is provided with appropriate installation instructions.

A tapped hole in a cast metal *enclosure* for the attachment of threaded rigid conduit must be provided with

a) an integral bushing having a smooth, rounded inlet hole with a diameter the same as the internal diameter of a standard bushing to provide protection for the conductors equivalent to that provided by such a bushing, or must be so located that a standard bushing can be attached to the end of the conduit, and
b) at least three full threads when tapped all the way through the wall of an *enclosure*, or with at least 3-1/2 full threads when used with an integral bushing.

It is assumed that *BDM/CDM/PDS* having a current rating or a horsepower rating with a full-load motor current as specified in Table S.29 or Clause S.204 is intended to be connected with wire of a size determined in accordance with Table 310-16 of the US National Electrical Code, ANSI/NFPA 70. Unless marked in accordance with 6.3.7.4.2 c) for use only with wire rated 75 °C (167 °F), the size is to be based upon wire rated for a temperature 60 °C (140 °F) for *BDM/CDM/PDS* rated 100 A or less; and upon wire rated for 75 °C for *BDM/CDM/PDS* rated greater than 100 A. The type of *insulation* is not specified.

S.4.11.10 Supply connections for pluggable *BDM/CDM/PDS*

S.4.11.10.1 Requirements for cords (for example *mains supply* cords)

Replacement of 4.11.10.1:

BDM/CDM intended to be cord-connected to the power supply must be provided with a length, size, and type of hard-service or junior hard-service flexible cord, such as type S, SJ, or the equivalent, evaluated for the use conditions, that is terminated in a grounding type attachment plug and is rated for the temperature and voltage involved.

A *BDM/CDM/PDS* can be cord-connected to the power supply when the *BDM/CDM/PDS* is

a) portable,

b) free standing or stationary (not *permanently connected* to building wiring), or

c) a device that is intended to provide a signaling function.

The cord ampacity, as specified in Table S.9 must not be less than the ampacity required for the *BDM/CDM/PDS* in S.4.11.11.2.

Table S.9 – Ampacity of flexible cord

Conductor size, AWG	Number of conductors	
	2	3 [a]
18	10	7
16	13	10
14	18	15
12	25	20
10	30	25
8	40	35
6	55	45
4	70	60
2	95	80

[a] Where more than three current-carrying conductors are provided, the ampacity of each of the conductors must be: 80 % of these values for 4 to 6 conductors; 70 % of these values for 7 to 9 conductors; 50 % of these values for 10 to 20 conductors; 45 % of these values for 21 to 30 conductors; 40 % of these values for 31 to 40 conductors; and 35 % of these values for 41 or more conductors.

Cord-connected *BDM/CDM/PDS* provided with a standard attachment plug whose ampere rating exceeds the ampacity of the power supply cord must be provided with an integral *overcurrent* protective device rated not more than the ampacity of the conductors. Cord-connected *BDM/CDM/PDS* provided with a multi-pin connector or without any attachment plug or connector must be

d) provided with integral *overcurrent* protection rated not more than the ampacity of the conductors, or

e) marked as in S.6.3.9.6.5 to indicate the ratings of the *overcurrent* protection required to be installed in the field.

Strain relief must be provided on power supply or signal multicable cords. The strain relief must be tested in accordance with S.5.2.2.200.

At the point at which the cord passes through the *enclosure* wall, protection must be provided to prevent cord abrasion.

When a knot serves as strain relief in an attached flexible cord, any surface that the knot contacts must be free from projections, sharp edges, burrs, fins and similar irregularities, that abrade *insulation* on the conductors.

Means must be provided to prevent the supply cord from being pushed into the *enclosure* of the *BDM/CDM/PDS* through the cord entry hole when such displacement results in

f) subjecting the supply cord to mechanical damage,
g) exposing the supply cord to a temperature higher than that for which it is rated,
h) reducing *clearance* and *creepage distances*, such as to a metal strain-relief clamp, below the minimum required values, or
i) damaging internal connections or *components*.

To determine compliance, the supply cord must be tested in accordance with S.5.2.2.200.2, push-back relief test.

A power-supply or signaling connecting cord, used on *BDM/CDM/PDS* having a

j) type 3, 3R, 3S, 4, 4X, 6, or 6P *enclosure* must be evaluated for outdoor use,
k) type 6 or 6P *enclosure* must be water resistant, and
l) type 12, 12K, or 13 *enclosure* must be oil resistant (such as SO, SJO, or STO).

For a device that is intended to provide a signaling function, an attachment plug is not required.

A lead that is intended to be spliced in the field to a circuit conductor must not be smaller than 18 AWG (0,82 mm^2) and the *insulation*, when of rubber or thermoplastic, must not be less than 1/32 in (0,8 mm) thick.

S.4.11.11 Terminals

S.4.11.11.1 Construction requirements

Addition to 4.11.11.1:

Terminals must comply with UL 310, UL 486A-486B, UL 486E or UL 1059 as appropriate. Terminals that will be wired in the field must be suitable for field wiring.

A pressure terminal connector, including one that is compression tool applied, for field connection to supply or load is not required to be provided for *BDM/CDM/PDS* with field wiring larger than 10 AWG (5,3 mm^2) when the construction complies with the following conditions.

a) *Component* terminal connectors are available from the *BDM/CDM/PDS* manufacturer and one or more are specified for field installation on the *BDM/CDM/PDS*.
b) A fastening device, such as a stud, nut, bolt, spring or flat washer, or similar device, that is required for installation is
    1) provided as part of the *component* terminal assembly, or
    2) mounted on or separately packaged with the *BDM/CDM/PDS*.

c) The installation of the terminal assembly does not involve the loosening or disassembly of a part other than a *cover* or other part giving access to the terminal location. The means for securing the terminal connectors must be accessible for tightening before and after installation of the conductor.

d) When the pressure connector provided in a *component* terminal assembly requires the use of a special tool for securing the conductor, instructions referencing use of the tool must be included with the *component* assembly or with the *BDM/CDM/PDS*.

e) Installation of a pressure terminal connector in the intended manner must result in a product that complies with the requirements in this document.

f) The *BDM/CDM/PDS* is marked in accordance with 6.3.7.4.2 d).

A terminal to which field wiring greater than 10 AWG (5,3 mm^2) is to be connected must be a soldering lug or pressure wire connector. A terminal to which a 10 AWG (5,3 mm^2) or smaller wiring connection is to be made must consist of a clamp or binding screw with a terminal plate having upturned lugs or the equivalent to hold the wire in position, or must be a soldering lug or pressure wire connector.

A wire-binding screw to which field wiring connections of conductors larger than 14 AWG (2,1 mm^2) are made must be no. 8 or larger.

A wire-binding screw intended only for field wiring connection of a conductor sized 14 AWG (2,1 mm^2) or smaller must be no. 6 or larger.

A terminal plate tapped for a wire-binding screw must be of metal not less than 0,030 in (0,76 mm) thick for a 14 AWG (2,1 mm^2) or smaller wire, and not less than 0,050 in (1,27 mm) thick for a wire larger than 14 AWG (2,1 mm^2). There must be at least two full threads in the plate unless fewer threads result in a secure connection in which the threads do not strip upon application of a 20 lb·in (2,3 Nm) tightening torque.

A terminal plate formed from stock having the required thickness specified above can have the metal extruded at the tapped hole for the binding screw to provide two full threads.

A wire-binding screw must thread into metal.

A *field wiring terminal* made with an aluminum body or intended for connection of aluminum wire must be rated AL7CU or AL9CU.

S.4.11.11.2 Connecting capacity of terminals

Replacement of 4.11.11.2, except the first paragraph, which applies:

The terminals of *BDM/CDM* must each be provided with wiring terminals or leads for connection of conductors having an ampacity as follows.

a) For supply terminals, not less than 125 % of maximum rated input current and not less than 125 % of full load motor current.

b) For motor load terminals, not less than 125 % of the maximum marked output current and not less than 125 % of the full-load motor current specified in Table S.29 or Table S.30 for output horsepower ratings.

c) For terminals of a DC bus circuit intended to supply one or more inverters, not less than 125 % of the maximum marked current for those terminals.

d) For power terminals not addressed in a), b), c) or e), not less than 100 % of the maximum marked current for those terminals.

e) Unless marked in accordance with S.6.3.7.4.1, for *BDM/CDM/PDS* controlling a DC motor intended to be operated from a rectified single-phase power supply:

1) 190 % of full load current when a half wave rectifier is used;
2) 150 % of full load current when a full wave rectifier is used.

Where field wiring conductors will be larger than 10 AWG (5,3 mm^2), the *field wiring terminals* or leads may be omitted in accordance with S.4.11.11.1.

The conductor size must be determined from the 60 °C or 75 °C column of Table S.10 based on the value calculated as above.

Unless marked otherwise, use the 60 °C wire for 100 A and less and 75 °C wire above 100 A.

For conductors in parallel, conductors must not be smaller than 1/0 AWG.

When a *field wiring terminal* can receive the next larger size conductor than that required in S.4.11.11.2, the terminal must comply with secureness and pullout requirements with that size conductor, unless the *BDM/CDM/PDS* is marked to restrict its use to only the smaller size conductor in accordance with S.6.3.7.4.1.

Table S.10 – Ampacities of insulated conductors

Wire size AWG (mm^2)		**60 °C (140 °F)**		**75 °C (167 °F)**	
		Copper	**Aluminum**	**Copper**	**Aluminum**
24	(0,2)	2	-	-	-
22	(0,3)	3	-	-	-
20	(0,5)	5	-	-	-
18	(0,8)	7	-	-	-
16	(1,3)	10	-	-	-
14	(2,1)	15	-	15	-
12	(3,3)	20	15	20	15
10	(5,3)	30	25	30	25
8	(8,4)	40	30	50	40
6	(13,3)	55	40	65	50
4	(21,2)	70	55	85	65
3	(26,7)	85	65	100	75
2	(33,6)	95	75	115	90
1	(42,4)	110	85	130	100
1/0	(53,5)	-	-	150	120
2/0	(67,4)	-	-	175	135
3/0	(85,0)	-	-	200	155
4/0	(107,2)	-	-	230	180
-	-	-	-	-	-
kcmil	-	-	-	-	-
250	(127)	-	-	255	205
300	(152)	-	-	285	230
350	(177)	-	-	310	250
400	(203)	-	-	335	270
500	(253)	-	-	380	310
600	(304)	-	-	420	340
700	(355)	-	-	460	375

Wire size AWG (mm^2)		**60 °C (140 °F)**		**75 °C (167 °F)**	
		Copper	**Aluminum**	**Copper**	**Aluminum**
750	(380)	-	-	475	385
800	(405)	-	-	490	395
900	(456)	-	-	520	425
1 000	(506)	-	-	545	445
1 250	(633)	-	-	590	485
1 500	(760)	-	-	625	520
1 750	(887)	-	-	650	545
2 000	(1 013)	-	-	665	560

These values of ampacity apply only when not more than three conductors are to be field-installed in the conduit. When four or more conductors, other than a neutral that carries the unbalanced current, are to be installed in a conduit (as occurs because of the number of conduit hubs provided in outdoor equipment, the number of wires required in certain polyphase *system*s, or other reasons), the ampacity of each of the conductors must be 80 % of these values when 4 to 6 conductors are involved, 70 % of these values when 7 to 24 conductors, 60 % of these values when 25 to 42 conductors, and 50 % of these values when 43 or more conductors.

NOTE 1 For multiple-conductors of the same size (1/0 AWG or larger) at a terminal, the ampacity is equal to the value in Table S.10 for that conductor multiplied by the number of conductors that the terminal accommodates.

Additional subclause to 4.11.11.2:

S.4.11.11.2.200 *Control circuit* terminals

Terminals for control, signal, or sensor circuits must accept 14 AWG (2,1 mm^2) minimum, unless marked (on the product or installation instructions) for the connection of 18 AWG (0,82 mm^2) and 16 AWG (1,3 mm^2) conductor size(s).

S.4.11.11.3 Connection to external conductors

S.4.11.11.4 Wire bending space for wires 10 mm2 and greater

Replacement of 4.11.11.4, including its title:

S.4.11.11.4 Wire bending space for wires 8 AWG (8,4 mm^2) and greater

The space between the end of the soldering lug or pressure wire connector for the connection of field-installed wire and the wall of the *enclosure* toward which the wire is directed upon leaving the lug or connector must be at least that specified in Table S.11.

The space specified above is to be the length of a straight line extending from the end of the soldering lug or pressure wire connector where the wire is connected toward and perpendicular to the *enclosure* wall toward which the wire is initially directed.

When a wire is restricted by barriers or other means from being bent where it leaves the connector, the distance required by Table S.11 is to be measured from the end of the barrier. A terminal lug or connector is to be repositioned anywhere within the limits to obtain the shortest distance for measurement.

The wire size used to determine the wire bending space is based on 125 % of the motor full-load current rating. See Table S.29 or Table S.30 for the full-load current rating of horsepower rated motors.

Table S.11 – Wire bending space at the terminals of enclosed power conversion equipment

Size of wire[a]		Minimum bending space, terminal to wall in (mm)					
		Wires per terminal					
AWG or kcmil	mm^2	1		2		3	
14 to 10	(2,1 to 5,3)	-	-	-	-	-	-
8 to 6	(8,4 to 13,3)	1-1/2	(38)	-	-	-	-
4 to 3	(21,2 to 26,7)	2	(51)	-	-	-	-
2	(33,6)	2-1/2	(64)	-	-	-	-
1	(42,4)	3	(76)	-	-	-	-
1/0	(53,5)	5	(127)	5	(127)	7	(178)
2/0	(67,4)	6	(152)	6	(152)	7-1/2	(191)
3/0	(85,0)	7	(178)	7	(178)	8	(203)
4/0	(107,2)	7	(178)	7	(178)	8-1/2	(216)
250	(127)	8	(203)	8	(203)	9	(229)
300	(152)	10	(254)	10	(254)	11	(279)
350	(177)	12	(305)	12	(305)	13	(330)
400	(203)	12	(305)	12	(305)	14	(356)
500	(253)	12	(305)	12	(305)	15	(381)
600	(304)	14	(356)	16	(406)	18	(457)
700	(355)	14	(356)	16	(406)	20	(508)
750 to 800	(380 to 405)	18	(457)	19	(483)	22	(559)
900	(456)	18	(457)	19	(483)	24	(610)

Where provision for more than three conductors per terminals is provided, the bending space must be in accordance with the appropriate tables for cabinets and boxes in Article 312 of the US National Electrical Code, ANSI/NFPA 70.

[a] The wire size is to be based on S.4.11.11.2.

Additional subclause to 4.11:

S.4.11.200 General

S.4.11.200.1 *Control circuit* wiring

Primary and secondary circuit internal wiring must be provided with additional protection when it is

a) connected to the load side of the branch-circuit short-circuit protection (see S.4.3.1),
b) located in a circuit that incorporates the coil of an internal or external motor control contactor (such as for bypass), and
c) sized from 22 AWG to 12 AWG (0,324 mm^2 to 3,3 mm^2).

Other than as noted in the following two paragraphs, the additional wiring protection required must

d) be located within the *BDM/CDM*,
e) be rated in accordance with Table S.13,
f) be provided in each ungrounded conductor,

g) be located no more than 12 in (305 mm) from the point where the wiring is connected to its source of power,

h) either be a supplementary or a branch-circuit type fuse in accordance with the UL 248 series or a branch-circuit breaker in accordance with UL 489, and

i) be provided with a marking in accordance with S.6.3.9.6.3 b).

The additional protection noted is not required to be included within the *BDM/CDM* when it is shipped from the factory and meets the following:

j) the manufacturer makes available a kit that complies with this section;

k) this kit is evaluated for field installation;

l) the *BDM/CDM* is marked in accordance with S.6.3.9.6.3 b) c).

The additional protection noted is not required to be shipped with the *BDM/CDM* when the fuseholder is included within the *BDM/CDM* and the unit is marked in accordance with S.6.3.9.6.3 d).

Table S.12 – *Overcurrent* protective device

Control-circuit wire Size, AWG mm^2		Maximum protective device rating A
22	(0,32)	3
20	(0,52)	5
18	(0,82)	7
16	(1,3)	10
14	(2,1)	20
12	(3,3)	25

For *BDM/CDM* with a short-circuit current rating in excess of 10 000 A, the additional wiring protection must be rated greater than or equal to the marked short-circuit current rating of the *BDM/CDM*. When fuses are used for this protection, they must be class CC, CF, G, J, L, R, or T and be provided with an appropriate branch-circuit type fuseholder. These fuses are not required to be factory installed.

Additional protection described in S.4.11.200.1 is not required in the following cases.

m) Wiring located in a class 1 power-limited or class 3 remote-*control circuit* or located in a class 2 (see S.203.1.5): limited voltage/current (see S.203.1.6), limited energy (see S.203.1.1) or limiting impedance (see S.203.1.8) secondary circuit is not required to be additionally protected.

n) Any wiring measuring a maximum of 12 in (305 mm) long is not required to be additionally protected.

o) Any wiring connected to a printed wiring board having no connections external to the *BDM/CDM* and having no more than casual contact with insulated or un-insulated parts of opposite polarity or with grounded parts is not required to be additionally protected.

p) When an instantaneous *trip* circuit breaker is used or intended for use as the branch-circuit short-circuit protection (see S.4.3.1) and its rating or *trip* setting is not more than the applicable value specified in Table S.13, then wiring is not required to be additionally protected when the *BDM/CDM* is marked in accordance with S.6.3.9.6.3 a).

Table S.13 – Branch-circuit *short-circuit protective device*

Control-circuit wire size, AWG mm^2		Maximum rating of branch-circuit protective device A	
		Conductors within *enclosure*	**Conductors outside *enclosure***
22	(0,32)	12	3
20	(0,52)	20	5
18	(0,82)	25	7
16	(1,3)	40	10
14	(2,1)	100	45
12	(3,3)	120	60

S.4.11.200.2 Other than *control circuit* wiring

S.4.11.200.2.1 Primary *overcurrent* protective device (not power circuit)

All wiring including bus bars and interconnecting cables used in the distribution of primary electric energy within and between units of *BDM/CDM/PDS* and all transformers and other loading devices connected to the primary circuit must be protected against burnout and damage to *insulation* resulting from any overload or short-circuit condition that occurs during operation of the *BDM/CDM/PDS*. The *overcurrent* protective device must be sized based on the levels identified in Table S.12 and Table S.13.

The protection referenced above must be provided by *overcurrent protective devices* included as integral parts of the *BDM/CDM/PDS* or, when rated in accordance with the following paragraphs, from the protection associated with the branch-circuit to which the *BDM/CDM/PDS* is connected.

Overcurrent protective devices that are provided within the *BDM/CDM/PDS* and are types that meet the requirements for branch-circuit protection in accordance with the US National Electrical Code, ANSI/NFPA 70 – for example, circuit breakers or class CC, CF, J, T, G, H, K, L, RK1, or RK5 cartridge fuses or type S fuses – comply with the requirement above. Other types of *overcurrent* protective devices are to be investigated to determine their acceptability for the application.

The ratings of an *overcurrent* protective device in series with connecting wiring must not exceed the following:

a) for motor loads alone: 300 % of the motor full-load current observed during the maximum normal operating conditions of the *system*;
b) for resistive loads, and for combination resistive and reactive loads, with or without motor loads: 250 % of the full-load current of the circuit under evaluation.

An *overcurrent* protective device must be of a type that is intended for use when supplied directly by the branch-circuit to which the *BDM/CDM/PDS* is connected unless additional protection intended for the use is provided in the *BDM/CDM/PDS*.

An *overcurrent* protective device must be connected between the ungrounded branch-circuit supply conductor and the load.

S.4.11.200.2.2 Secondary *overcurrent* protective device

All external secondary circuit interconnecting cables and all secondary circuit wiring between units must be protected against burnout and damage to the *insulation* resulting from any overload or short-circuit condition that occurs during use of the *BDM/CDM/PDS*.

The *overcurrent* protective device provided in the primary circuit of a transformer is considered to provide protection for the secondary circuit wiring, when it operates to protect the secondary circuit under all overload conditions including short-circuit.

A conductor provided with *overcurrent* protection complying with the US National Electrical Code, ANSI/NFPA 70, complies with the requirements of S.4.11.200.2.2.

Secondary circuits that are derived from power supplies or other sources are not prohibited from being used when the output wiring carries the maximum current available from the power supply without discolouration or softening of *insulation*, and when the power supplies or other sources

a) are inherently limited, or
b) include sensing devices whose operation achieves the same result (prevention of burnout and damage to *insulation* resulting from overload) or de-energizes the *BDM/CDM/PDS*.

S.4.11.200.3 Securement of *live part*s

Other than as noted in the following paragraph, an un*insulated live part*, including a terminal, must be secured to its supporting surface by a method other than friction between surfaces so that it is prevented from turning or shifting in position when such motion results in a reduction of the required *clearance* and *creepage distances*.

A pressure terminal connector is not required to be prevented from turning when no *clearance* and *creepage distances* less than those required result when the terminals are turned 30° toward each other, or toward other uninsulated parts of opposite polarity, or toward grounded metal parts.

A live screwhead or nut on the underside of an insulating base must be prevented from loosening and must be insulated or spaced from the mounting surface. This is accomplished by

a) countersinking parts by at least 1/8 in (3,2 mm) and covering them with a waterproof, insulating sealing compound that does not degrade at 15 °C (27 °F) higher than its normal operating temperature and not less than 65 °C (149 °F), or
b) securing such parts and insulating them from the mounting surface by a barrier, or the equivalent, or by *clearances* and *creepage distances* specified elsewhere in this document.

S.4.12 Mechanical requirements for *enclosures*

Replacement of 4.12:

S.4.12.200 General

In the USA, *enclosure*s must comply with the requirements contained in UL 50 and UL 50E, with the exception that Annex S supplements, modifies, or replaces the specified requirements in UL 50 and UL 50E for *enclosure*s provided with equipment covered by this document.

In the US, motor *enclosure* requirements are provided in UL 2111 and the UL 1004 series of standards.

S.4.12.201 Construction

S.4.12.201.1 Additions to Section 6 of UL 50:2015

BDM/CDM with incomplete or partial *enclosures* are evaluated as open devices with respect to the performance requirements in this document.

For an *enclosure* provided with multiple compartments, when marked in accordance with S.4.12.203.3, the individual compartments can be evaluated to different *enclosure* type requirements when the compartments are completely separated by a wall or barrier and

a) the assembly is intended for indoor use and the compartments are rated type 1, 2, 4, 4X, 5, 6, 6P, 12, 12K, 13, or
b) the assembly is intended for outdoor use and the compartments are rated type 3, 3R, 3S, 4, 4X, 6, or 6P.

S.4.12.201.2 Additions to Table 1 and Table 2 of UL 50:2015

A 4X indoor use only *enclosure* is defined as a polymeric *enclosure* for indoor use primarily to provide a degree of protection against dust, splashing water and hose-directed water. See S.6.2.1 for marking. These *enclosures* are not intended for applications where exposed to icing.

S.4.12.201.3 Environmental rating related to *enclosure* performance

Other than as noted in the following paragraph, an *enclosure* must comply with the environmental rating related performance requirements in Table 2 (Applicable design tests) of UL 50E:2020, as they apply to the type number or numbers with which the *enclosure* is marked.

A type 4X *enclosure* intended for indoor use only and marked in accordance with S.6.2.1 must comply with the requirements for a type 4X *enclosure* with the following exceptions:

a) it is not required to be subjected to the external icing test, in UL 50E;
b) for a polymeric *enclosure*, it is not required to have a material which is resistant to ultraviolet light weathering in accordance with UL 50E.

A type 12 *enclosure* may employ filtered ventilation openings if it complies with the requirements for type 12 *enclosures*, UL 50E.

BDM/CDM/PDS marked other than type 1 is permitted to have *insulated live parts* external to the primary *enclosure* or have portions of *insulated live parts* projecting through the wall of the primary *enclosure*, provided

c) the external or projecting *insulated live parts* are within a housing complying with all the requirements for a type 1 *enclosure*,
d) the material of the housing complies with the material requirements for the *BDM/CDM/PDS* type designation, and
e) the external or projecting *insulated live parts* comply with the environmental requirements for the *BDM/CDM/PDS* type designation.

NOTE The *insulation* of the *live parts* can be used to comply with the requirements for the housing if it meets the appropriate requirements.

Where provided with forced ventilation or any other fans, environmental tests must be conducted separately with the associated fans energized and unenergized.

Insulated live parts or portions of *insulated live parts* which extend through a primary type 12 *enclosure* must be protected from dripping non-corrosive liquids and circulating dust by either of the following methods.

f) If protection from dripping non-corrosive liquids is provided by *electrical insulation* integral to the *insulated live parts*, the *insulation* material must meet the requirements for flame rating, RTI, HWI, HAI, and CTI as described in 4.4.7.8.2, and additionally the requirements for volume resistivity and dielectric strength, both of UL 746C, following exposure to water per water exposure and immersion of UL 746C.

g) If protection from dripping liquids is provided by mechanical means such as a cavity, channel, hood, or guard, the construction must inhibit contact with dripping liquids when the assembly including primary *enclosure* is subjected to the drip test of UL 50E with the *enclosure* mounted in all orientations allowed.

h) Protection from circulating dust must be verified by either the dust test or the atomized water test of UL 50E. At the conclusion of either the dust test or atomized water test, no contaminants (dust particles or water droplets) are allowed to be in contact with un*insulated live parts* other than un*insulated live parts* in limited voltage/current circuits, as described in Clause S.203, that might be exposed in places such as the windings of a cooling fan supplied by a limited voltage/current source. Water droplets or dust particles are allowed to contact insulating material. Verification of contaminant ingress is to be accomplished by disassembly and *visual inspection* in 5.2.1 immediately following the conclusion of the test.

Insulated live parts or portions of *insulated live parts* which extend through a primary type 4 or 4X *enclosure* must be protected from rain, splashing water, and hose-directed water by either of the following methods.

i) If protection from rain, splashing water, and hose-directed water is provided by *electrical insulation* integral to the *insulated live parts*, the *insulation* material must meet the requirements for flame rating, RTI, HWI, HAI, and CTI as described in 4.4.7.8.2 and additionally the requirements for volume resistivity and dielectric strength, both of UL 746C, following exposure to water per water exposure and immersion, of UL 746C.

j) If protection from rain, splashing water, and hose-directed water is provided by mechanical means such as a cavity, channel, hood, or guard, the construction must inhibit contact with rain, splashing water, and hose-directed water when the assembly including primary *enclosure* is subjected to the hosedown test of UL 50E with the *enclosure* mounted in all orientations allowed.

k) Protection from water must be verified by the hosedown test of UL 50E. At the conclusion of either the hosedown test, no water is allowed to be in contact with un*insulated live parts* other than un*insulated live parts* in limited voltage/current circuits, as described in Clause S.203, that might be exposed in places such as the windings of a cooling fan supplied by a limited voltage/current source. Water is allowed to contact insulating material. Verification of water ingress is to be accomplished by disassembly and *visual inspection* in 5.2.1 immediately following the conclusion of the test.

A snap-on *cover* providing part of the overall *enclosure* that gives access to un*insulated live parts* and does not have a separate tool-operated fastener must have no apparent means for removal such as an extending tab, and must comply with S.4.12.202.2.

S.4.12.201.4 Polymeric *enclosure*s/parts

Addition to 6.6 of UL 50:2015:

For an adhesive that secures a part closing an opening in an *enclosure*, the adhesive must comply with the requirements for adhesives in UL 746C. The adhesive for a part of a *component* is not required to comply with this requirement when the device complies with the accessibility and *enclosure* requirements without the part in place.

A type 4X (indoor only) *enclosure* is not required to have an adhesive that is resistant to ultraviolet light weathering in accordance with UL 746C.

S.4.12.201.5 Electrical continuity

Replacement of 6.6.2 of UL 50:2015:

Requirements in 4.4.4.2 of UL 50:2015 replace the requirements in 6.6.2 of UL 50:2015.

S.4.12.201.6 Openings in *enclosure*s

S.4.12.201.6.1 General

Addition to 6.3 of UL 50:2015:

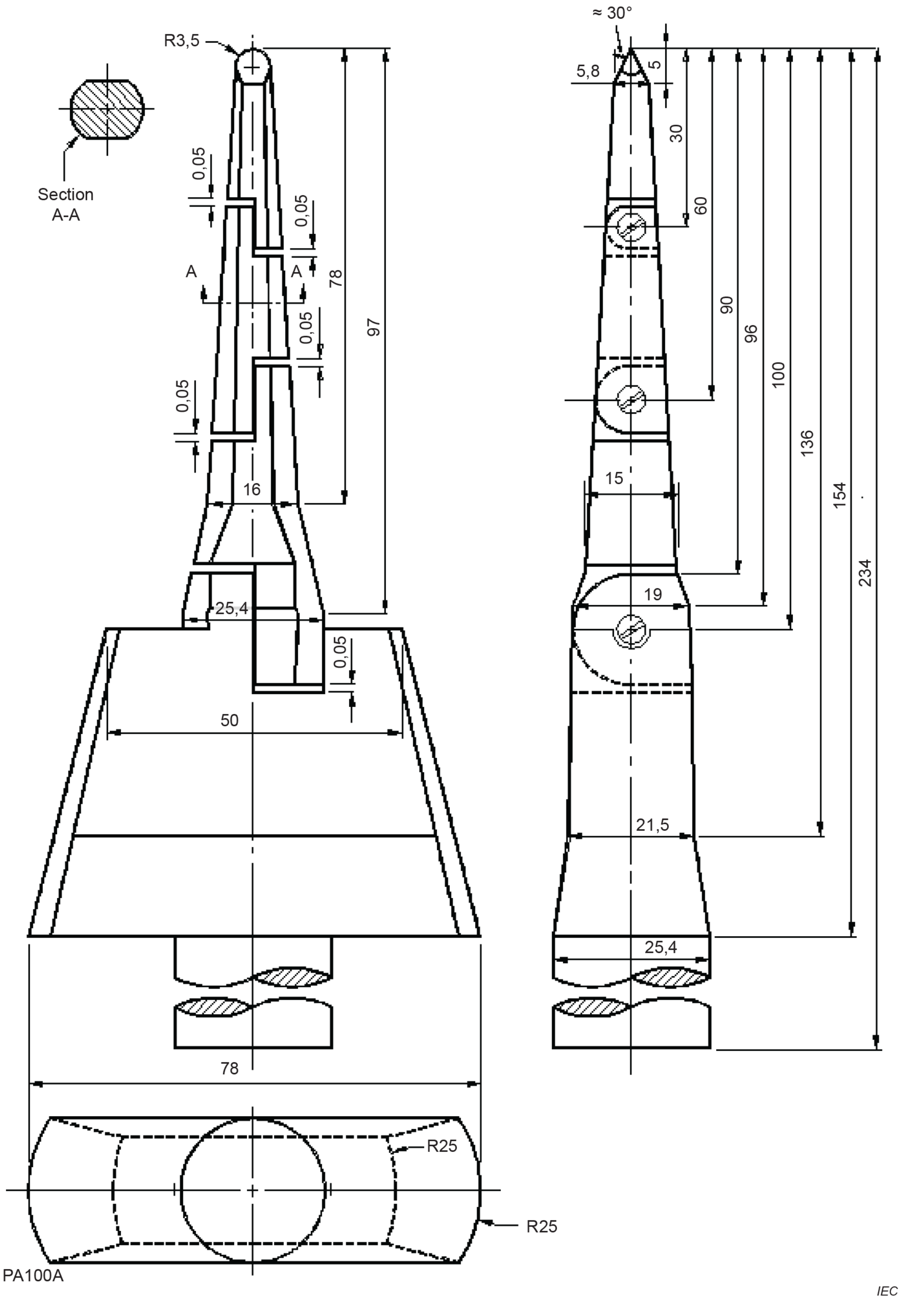
An opening not used for ventilation must prevent entry of a 0,500 in (12,70 mm) diameter rod. All such openings must comply with the requirements in S.4.12.201.4 and S.4.12.201.6.2.

No covering is required across the bottom of a type 1, 2, 3R, or 3RX *enclosure* of a floor-mounted controller when the *enclosure* is within 6 in (152 mm) of the floor or less and when *live parts* within the device are at least 6 in (152 mm) above the highest portion of the lower edge of the *enclosure*.

S.4.12.201.6.2 Accessibility of live or moving parts

To reduce the risk of unintentional contact that may involve a risk of electric shock or injury, the probe illustrated in Figure S.1 or in accordance with the jointed test finger according to Figure M.2 must not contact an un*insulated live parts* or wire, electrical energy – high current levels, or moving parts when inserted through any opening in an *enclosure*.

Dimensions in millimetres



PA100A

Figure S.1 – Articulate probe with web stop

S.4.12.201.6.3 Equipment openings

Replacement for 7.3.2 of UL 50E:2020:

Openings in *enclosures* must be filled by devices with suitable environmental ratings as specified in Table S.14. The device may be field installed if the *enclosure* is marked in accordance with 6.3.11.

Table S.14 – Openings in *enclosures*

***Enclosure* type**	**Required environmental type rating for devices closing openings in *enclosure*s**
2	2, 3, 3R, 3S, 4, 4X, 5, 6, 6P, 12, 13
3	3, 3S, 4, 4X, 6, 6P
3R	3, 3R, 3S, 4, 4X, 6, 6P
3S	3, 3S, 4, 4X, 6, 6P
4	4, 4X, 6, 6P
4X	4X
5	3, 3R, 3S, 4, 4X, 5, 6, 6P, 12, 13
6	6, 6P
6P	6P
12, 12K	12, 13
13	13

S.4.12.201.6.4 Ventilation openings

A louver must not be more than 1 ft (305 mm) long. The area of an opening covered by a louver, a perforated or an expanded-metal mesh panel that is thinner than the *enclosure* must not exceed 1,39 ft^2 (0,129 m^2).

The diameter of the wires of a screen must be at least 0,05 in (1,30 mm) when the screen openings are 0,05 in^2 (32,3 mm^2) or less in area, and must be at least 0,08 in (2,03 mm) for larger screen openings.

Other than as noted in the following paragraph, perforated sheet steel and sheet steel employed for expanded-metal mesh must be at least 0,04 in (1,07 mm) thick for mesh openings or perforations 0,5 in^2 (3,2 cm^2) or less in area, and must be at least 0,08 in (2,03 mm) thick for larger openings.

In a small device where the indentation of a guard or *enclosure* does not alter the *clearance* between uninsulated, movable, *live parts* and grounded metal so as to arsely affect the performance or reduce the *clearance* and *creepage distances* below the minimum value specified in the product standard, expanded-metal mesh of steel not less than 0,2 in (0,58 mm) thick can be provided when

a) the exposed mesh on any one side or surface of the device so protected has an area not more than 71,9 in^2 (464 cm^2) and has no dimension greater than 1 ft (305 mm), or
b) the width of the opening so protected is not greater than 3,5 in (88,9 mm).

Any ventilation opening in an *enclosure* must not permit the entrance of a rod having a diameter of 0,500 in (12,7 mm) if un*insulated live part*s are 4 in (102 mm) or less from the opening. When the distance between un*insulated live part*s and the opening is more than 4 in (102 mm), the opening must not permit the entrance of a rod having a diameter of 0,750 in (19,05 mm).

S.4.12.201.6.5 Forced ventilation

When compliance to S.4.12.200 is required by S.4.4.200, a polymeric blower motor body is accessible due to openings in the *BDM/CDM enclosure*, the blower motor body must comply with the polymeric *enclosure* tests required by S.4.12.201.2. Accessibility is to be determined in accordance with S.4.12.201.4.

When compliance to S.4.12.200 is required by S.4.4.200, and other than as noted in the following paragraph, when openings in the *BDM/CDM enclosure* expose a blower motor body (either metal or polymeric) to water or dust during any testing in accordance with S.4.12.201.1 (environmental rating related to *enclosure* performance), the blower motor body must protect the blower motor windings from exposure to this water or dust. The ability of the body to protect the windings must be determined with and without the blower motor operating.

Openings for a blower motor *enclosure* are not required to meet the requirements for water or dust testing in accordance with S.4.12.201.1 (environmental rating related to *enclosure* performance) when

a) the overall *BDM/CDM enclosure* is divided into two separate parts – one part housing primarily the blower motor and the other part housing the majority of the electrical parts, and
b) the part of the overall *enclosure* housing the blower motor is marked with a type 1 environmental rating regardless of the environmental rating of the other part of the overall *enclosure*.

S.4.12.201.6.6 Observation windows

Glass covering an observation opening and forming a part of the *enclosure* must be reliably secured in such a manner that it is not readily displaced in service and must provide mechanical protection of the *enclosed* parts. Glass for an opening not more than 4 in (102 mm) in any dimension must not be less than 0,055 in (1,40 mm) thick; and glass for an opening having no dimension greater than 12 in (305 mm) must not be less than 0,115 in (2,92 mm) thick. Glass used to cover a larger opening must have the required mechanical strength and must otherwise be usable for the purpose.

S.4.12.201.7 Thickness of sheet-metal *enclosure*s

The thickness of a sheet-metal *enclosure* must be either

a) not less than specified in Table S.15 and Table S.16, or
b) thinner than specified in Table S.15 and Table S.16 and tested in accordance with the comparative deflection test, Section 8.1 of UL 50:2015, and the deflection test, Section 8.2 of UL 50:2015.

Table S.15 – Addition to Table 3 of UL 50:2015: Thickness of sheet metal for *enclosure*s – Carbon steel or stainless steel

Without supporting frame[a]		With supporting frame or equivalent reinforcement[a]		Minimum thickness
Maximum width[b]	**Maximum length[c]**	**Maximum Width[b]**	**Maximum length**	**Uncoated**
cm	cm	cm	cm	mm
10,2	Not limited	15,9	Not limited	0,51[d]
12,1	14,6	17,1	21,0	--
15,2	Not limited	24,1	Not limited	0,66[d]
17,8	22,2	25,4	31,8	--
20,3	Not limited	30,5	Not limited	0,81
22,9	29,2	33,0	40,6	--
31,8	Not limited	49,5	Not limited	1,07
35,6	45,7	53,3	63,5	--

[a] See S.4.12.201.7

[b] The width is the smaller dimension of a rectangular piece of sheet metal that is part of an *enclosure*. Adjacent surfaces of an *enclosure* can have supports in common and be made of a single sheet.

[c] Not limited applies only when the edge of the surface is flanged at least 12,7 mm or fastened to adjacent surfaces not normally removed in use.

[d] Sheet steel for an *enclosure* intended for outdoor use or at points to which a wiring *system* is to be connected must not be less than 0,81 mm thick.

Table S.16 – Addition to Table 4 of UL 50:2015: Thickness of sheet metal for *enclosure*s – Aluminum, copper or brass

Without supporting frame[a]		With supporting frame or equivalent reinforcement[a]		Minimum thickness
Maximum width[b]	**Maximum length[c]**	**Maximum width[b]**	**Maximum length**	**Uncoated**
cm	cm	cm	cm	mm
7,6	Not limited	17,8	Not limited	0,58[d]
8,9	10,2	21,6	24,1	--
10,2	Not limited	25,4	Not limited	0,74[d]
12,7	15,2	26,7	34,3	--
15,2	Not limited	35,6	Not limited	0,91
16,5	20,3	38,1	45,7	--
20,3	Not limited	48,3	Not limited	1,14
24,1	29,2	53,3	63,5	--
30,5	Not limited	71,1	Not limited	1,.47
35,6	40,6	76,2	94,0	--

[a] See S.4.12.201.7.

[b] The width is the smaller dimension of a rectangular piece of sheet metal that is part of an *enclosure*. Adjacent surfaces of an *enclosure* can have supports in common and be made of a single sheet.

[c] Not limited applies only when the edge of the surface is flanged at least 12,7 mm or fastened to adjacent surfaces not normally removed in use.

[d] Sheet copper, brass, or aluminum for an *enclosure* intended for outdoor use must not be less than 0,74 mm thick. Sheet copper, brass, or aluminum for an *enclosure* at points to which a wiring *system* is to be connected must not be less than 1,14 mm thick.

S.4.12.201.7.1 Supporting frame

Replacement of 6.4.1.3 of UL 50:2015:

Constructions without supporting frame include

a) a single sheet with single formed flanges – formed edges,

b) a single sheet that is corrugated or ribbed,

c) an *enclosure* surface loosely attached to a frame, for example, with spring clips, and

d) an *enclosure* surface having an unsupported edge.

S.4.12.201.8 Joints and fastenings

Section 6.4.2 of UL 50:2015 does not apply.

S.4.12.201.9 Notches

Section 6.4.3 of UL 50:2015 does not apply.

S.4.12.201.10 *Cover*s and *door*s

S.4.12.201.10.1 General

Where renewal of a fuse or any other *overcurrent* protective device requires access to the interior of an *enclosure*, the *enclosure* must be provided with a *door* providing access to that device. A *door* must also be provided where access to the interior of an *enclosure* is required under normal operating conditions.

Substitution of a *cover* for a *door* is permitted when

a) access is required only in the event of burnout of a current element or similar devices on short-circuit,

b) the only fuse enclosed is a control-circuit fuse, when the fuse and control-circuit load are within the same *enclosure*,

c) the only fuse enclosed is a control-circuit fuse and the control-circuit load is a fixed load, such as a pilot lamp,

d) a means is provided for resetting all overload-protective devices from outside the *enclosure*, or kits are available to provide a means for resetting all overload-protective devices from outside the *enclosure* and a marking is provided in accordance with 6.2.2, and

e) the *cover* is interlocked such that the *BDM/CDM/PDS* is inoperable with the *cover* removed and the *cover* is marked as noted in S.6.5.1.

S.4.12.201.10.2 *Door* and *cover* thickness

Replacement of 6.7.2 of UL 50:2015:

The thickness of a sheet-metal *cover* or *door* must be either

a) not less than specified in Table S.15 and Table S.16, or

b) thinner than specified in Table S.15 and Table S.16 and tested in accordance with 8.2 of UL 50:2015, deflection test.

S.4.12.201.10.3 Fastening means

Replacement of 6.7.3 of UL 50:2015:

A part of an *enclosure*, such as a *door* or *cover*, must be provided with a means, such as latches, locks, interlocks, or screws for firmly securing it in place. A snap-on *cover* that complies with the requirements in S.4.12.202.2 is not required to have additional securing means.

S.4.12.201.10.4 Notched flanges

6.7.4 of UL 50:2015 does not apply.

S.4.12.201.10.5 Depth of flanges (flanges and rabbets)

Addition to 6.7.5 of UL 50:2015:

A *door* or *cover* giving access to a fuse or any portion of a circuit breaker other than the operating handle must comply with the following.

a) The *door* or *cover* must have flanges for the full length of the four edges. A combination of flange and rabbet can be used.
b) For an *enclosure* rated type 1 only, the gap distance between the flanges on the *door* or *cover* and the outside wall can be greater than those specified when the construction complies with the applicable performance requirements under short-circuit conditions and accessibility of *live parts*, S.4.12.201.4.
c) The flanges on the *door* or *cover* are not required to fit closely on the outside wall when a gasket evaluated for the application provides the intended tight fit.

S.4.12.201.10.6 Latches and handles

Replacement of 6.9.1 of UL 50:2015:

A *door* provided must be provided with a snap latch or a captive multi-turn or partial-turn fastener. Such securing means must be located or used in multiple so as to hold the *door* closed over its entire length. A captive fastener must be operable by hand or by a simple hand tool such as a screwdriver. An *enclosure* that is not required to comply with S.4.12.201.8 can use a *door* secured with noncaptive fasteners.

Requirement 6.9.4 of UL 50:2015 does not apply.

Requirement 6.9.5 of UL 50:2015 does not apply.

Requirement 6.9.6 of UL 50:2015 does not apply.

S.4.12.201.11 Connections for wiring *system*s

Addition to 6.10.1.2 of UL 50:2015:

Where the *enclosure* material is less than 0,053 in (1,35 mm) thick, the closure minimum thickness may be less than 0,053 in (1,35 mm) but not less than the thickness of the *enclosure* material.

Replacement of 6.10.4.4 of UL 50:2015:

When the threads for the connection of conduit are not tapped all the way through a hole in an *enclosure* wall, or conduit hub, there must not be less than 3-1/2 full threads in the metal and the edges of the inlet hole must be smooth and round.

Addition to 6.10.2 of UL 50:2015:

The dimensions of any knockout provided on the *enclosure* must be in accordance with Table S.17.

Table S.17 – Dimensions of knockout

Trade size in	Metric designator	Diameter of conduit opening			
		Minimum		Maximum	
		mm	(in)	mm	(in)
1/2	16	21,84	0,860	23,01	0,906
3/4	21	27,78	1,094	28,98	1,141
1	27	34,51	1,359	35,71	1,406
1-1/4	35	43,66	1,719	44,86	1,766
1-1/2	41	49,73	1,958	51,21	2,016
2	53	61,80	2,433	63,50	2,500
2-1/2	63	74,63	2,938	76,20	3,000
3	78	91,00	3,583	92,08	3,625
3-1/2	91	103,20	4,063	105,56	4,156
4	103	--	--	--	--

S.4.12.202 Performance

S.4.12.202.1 General

Addition to 8.1 of UL 50:2015:

An *enclosure* having multiple compartments must have each compartment subjected to the applicable tests for its respective *enclosure* type designation. The internal barrier between compartments is not required to be directly subjected to these tests. Any joints and gasket materials between compartments must be subjected to the environmental tests which are the most severe for either compartment.

An external operating means – such as those for a disconnect, a pilot device, or a resetting operation mounted on or through an *enclosure* – must withstand the tests specified for the *enclosure* unless otherwise indicated.

S.4.12.202.2 Securement of snap-on *cover*

The tests are to be conducted in the as-received condition and after the *cover* has been removed and replaced 10 times.

A snap-on *cover* providing part of the overall *enclosure* that gives access to un*insulated live parts* and does not have a separate tool-operated fastener must have no apparent means for removal such as an extending tab, and must comply with the following.

a) A *cover* that could be disengaged from the *enclosure* by a squeezing force applied with one hand must not be released when a squeezing force of 14 lbf (62 N) or less is applied at any two locations not more than 5 in (127 mm) apart. The distance is to be measured by a tape stretched tightly over that portion of the surface of the *cover* that are encompassed by the palm of the hand.
b) A *cover* must not disengage from the *enclosure* when a direct pull force of 14 lbf (62 N) is applied by gripping the *cover* at any two convenient locations.

c) A *cover* must not be disengaged from the *enclosure* by an impact force of 1 ft-lb (1,4 J) applied to the accessible faces of the *cover* – one blow per face. The impact is to be applied by a steel ball having a diameter of not less than 2 in (51 mm).

S.4.12.202.3 Polymeric *enclosure* rigid metallic conduit connection tests

S.4.12.202.3.1 Torque test

Addition to 8.6.3 of UL 50:2015:

Lower torque values can be used for the test when a marking is provided per S.4.12.203.

S.4.12.203 Marking

S.4.12.203.1 General

Replacement of Section 7 of UL 50:2015:

Polymeric *enclosure*s that require a lower torque value as specified in S.4.12.202.3.1 must be marked with the following or the equivalent:

"Tighten to __N m. Overtorquing results in *enclosure* breakage."

BDM/CDM/PDS employing a special fitting for the connection to a specific wiring *system* must be marked as specified in 6.3.7.

BDM/CDM/PDS that has been evaluated for installation with a nonmetal-*enclosed* wiring *system* only must be marked to indicate that it must be installed with such a wiring *system*.

S.4.12.203.2 Environmental related markings

9.2.3 of UL 50E:2020 does not apply.

9.5.2 through 9.5.4 of UL 50E:2020 do not apply.

S.4.12.203.3 Environmental related marking for individual compartments

Enclosures with multiple compartments complying with S.4.12.201.1 must be marked to clearly indicate the type designations for each of the individual compartments.

S.4.12.204 Position of operating handles

When a circuit breaker or switch is mounted such that movement of the operating handle, either vertically or rotationally, between the on and off positions results in one position being above the other position, the upper position must be the on position. The requirement does not apply to a circuit breaker or switch that is operated horizontally or that is operated rotationally and the on and off positions are at the same level, nor to a switching device having two on positions, such as a transfer switch or a double throw switch.

All floor-mounted *BDM/CDM/PDS* must comply with the following requirements. Wall mounted *BDM/CDM/PDS* with *enclosures* taller than 79 inches (2,0 m) must be considered to be floor-mounted *BDM/CDM/PDS* with respect to these requirements.

External handles and push-buttons must be located in accordance with the following.

a) Every switch and circuit breaker handle must be installed such that the handle is not more than 79 inches (2,0 m) above the floor.
b) Operating handles requiring more than 50 lbf (222 N) to operate must not be higher than 66 inches (1,7 m) in either the open or closed position.

In determining compliance of the location of external handles and push-buttons, measurements must be made to the center of the handle grip with the handle in the highest possible position. Where the handle grip is not clearly defined, it must be considered to be at a point 3 inches (76 mm) in from the end of the handle.

If the mechanism of a switching device is such that automatic operation of a switch, or operation of a remote or automatic tripping devices will permit sudden movement of an operating handle, the motion of the handle must be restricted or the handle must be guarded to prevent injury to persons in the vicinity of the handle.

Additional subclauses to Clause 4:

S.4.200 Auxiliary device

Auxiliary device such as *port*able programmers intended to be used only on a temporary basis, to diagnose or program *BDM/CDM/PDS* must comply with the requirements in UL 60950-1. These units must be evaluated as a subsystem of the *BDM/CDM/PDS*.

S.4.201 *Accessories*

BDM/CDM/PDS having provision for the use of an *accessory* to be attached in the field must comply with the requirements in this document with the *accessory* installed, and the *accessory* must comply with the requirements for the *BDM/CDM/PDS* for which it is intended. See 6.2.2.

As part of the investigation, an *accessory* must be tested and trial-installed. The *accessory* must be capable of being installed, and the instructions must be detailed and accurate. The installation must be capable of being accomplished using tools that are readily available unless a special tool is provided with the *accessory*.

S.4.202 Provisions for mounting

Provisions must be made for securely mounting *BDM/CDM* to a supporting surface. A bolt, screw, or other part used to mount a *component* of the *BDM/CDM/PDS* must not be used for securing the *BDM/CDM/PDS* to the supporting surface.

S.4.203 Capacitors

A bus capacitor must be rated for the voltage and the temperature of the circuit involved. This rating must be based on the continuous *working voltage* rating and the transient overvoltage rating (see 4.4.7.3).

An across-phase capacitor must be rated for the voltage (square root of 2 times the input value) and the temperature rating of the circuit involved and it must comply with the AC or DC voltage test in 5.2.3.4.

Other than as noted in the following paragraph, a motor starting capacitor employing a liquid dielectric medium more combustible than askarel must comply with the protected oil filled capacitor requirements contained in UL 810, including faulted *overcurrent* conditions based on the short-circuit rating of the *BDM/CDM*. A motor starting capacitor and any associated solid state *component* must be evaluated in accordance with the breakdown of *component* test in 5.2.4.10.

When the available fault current is limited by other *components* in the circuit such as a motor-start winding, the capacitor can be tested using a fault current less than the value as required by the breakdown of *component* test in S.5.2.4.1, and not less than the current established by dividing the rated circuit voltage by the impedance of the other *components*.

A non-motor starting capacitor employing a liquid dielectric medium more combustible than askarel, and any associated solid-state *component*, is only required to be evaluated in accordance with the breakdown of *component* test in 5.2.4.10.

S.5 Test requirements

S.5.1 General

S.5.1.1 Test objectives and classification

S.5.1.2 Selection of test samples

S.5.1.3 Sequence of tests

S.5.1.4 Earthing conditions

S.5.1.5 General conditions for tests

Addition to 5.1.5:

Tests are to be conducted at rated frequency and a test potential not less than 120 V, 208 V, 240 V, 277 V, 480 V, or 600 V as appropriate for the voltage ratings. See Table S.18. The temperature test must be conducted at a potential between 90 % to 110 % of the potential specified when the load current is adjusted to produce the maximum normal heating.

Table S.18 – Values of voltage for tests

Voltage rating of *BDM/CDM/PDS*[a]					
110 to 120	**220 to 240**	**254 to 277**	**380 to 415**	**440 to 480**	**560 to 600**
120	240	277	415	480	600

[a] If the rating of the *BDM/CDM/PDS* does not fall within any of the indicated voltage ranges, it is to be tested at its rated voltage.

Unless indicated otherwise, the tests are to be conducted at any *ambient temperature* within the range of 10 °C to 40 °C (50 °F to 104 °F). The *ambient temperature* is to be determined using either thermometers or thermocouples placed adjacent to the *BDM/CDM/PDS* being tested.

During the tests, *BDM/CDM/PDS* must be mounted and wired so as to represent the intended use. All *field wiring terminal* blocks or wire connectors must be tightened to the value of torque marked on the product.

BDM/CDM intended to control a variable speed motor load is to be tested controlling

a) a load equivalent to that of a motor with voltage, frequency, and current ratings corresponding to the marked rating,
b) a test motor capable of being loaded to the values specified, or
c) a simulation of the test motor by a passive load consisting of resistive or inductive loads.

S.5.1.6 Compliance

Addition to 5.1.6.

Devices or *systems* that result in termination of a test must be additionally evaluated to determine their suitability for the application.

S.5.2 Test specifications

S.5.2.1 *Visual inspections* (*type test*, routine test *and* sample *test)*

S.5.2.2 Mechanical tests

S.5.2.2.1 *Clearances* and *creepage distances* test (*type test*)

S.5.2.2.2 Non-accessibility test (*type test*)

Replacement of 5.2.2.2:

To reduce the risk of unintentional contact that may involve a risk of electric shock or injury, the probe referenced in S.4.12.201.6.2 must not contact an un*insulated live part* or wire, electrical energy – high current levels, or moving parts when inserted through any opening in an *enclosure*.

The probe specified in S.4.12.201.6.2 must be applied in any possible configuration; and, if necessary, the configuration must be changed after insertion through the opening.

The probe specified in S.4.12.201.6.2 is to be applied with a force not to exceed 2,2 lbf (10 N). The probe is to be used to determine the accessibility provided by an opening, and not as an instrument to determine the strength of a material.

The probe specified in S.4.12.201.6.2 is to be inserted as described above into all openings, including those in the bottom of the unit. For a floor-standing unit, the probe is to be inserted into all openings in the bottom that are accessible without tipping, turning over, or otherwise moving the unit from its intended installed position. For units other than floor-standing units, the unit is to be moved in whatever way necessary to make the entire bottom accessible for insertion of the probe.

S.5.2.2.3 Ingress protection test (IP rating) (*type test*)

Replacement of 5.2.2.3:

Enclosures must comply with S.4.12.

S.5.2.2.4 *Enclosure* integrity test (*type test*)

Replacement of 5.2.2.4:

Enclosures must comply with S.4.12.

S.5.2.2.5 Wall or ceiling mounted test (*type test*)

Replacement of 5.2.2.5:

Enclosures must comply with S.4.12.

Additional subclause to 5.2.2:

S.5.2.2.200 Cord and plug connected devices

S.5.2.2.200.1 Strain relief test

This test replaces 5.2.2.7.

The device provided with a strain relief as in S.4.11.10.1 must withstand a direct pull of 35 lbf (156 N) applied to the cord for 1 min. There must be no damage or displacement of the cord or conductors. Supply connections within the *BDM/CDM/PDS* are to be disconnected from terminals or splices during the test.

A field wiring lead must withstand without damage or displacement a direct pull of

a) 20 lbf (90 N) for 1 min applied to a lead extending from the *enclosure* such as through a hub or nipple, and
b) 10 lbf (44,5 N) for 1 min applied to a field wiring lead within a wiring compartment or an outlet box.

S.5.2.2.200.2 Push-back relief test

To determine compliance with S.4.11.10.1, a product must be tested in accordance with S.5.2.2.200.2 without occurrence of any of the following conditions:

a) subjecting the supply cord to mechanical damage;
b) exposing the supply cord to a temperature higher than that for which it is rated;
c) reducing *clearance* and *creepage distances* such as to a metal strain-relief clamp, below the minimum required values;
d) damaging internal connections or components.

The supply cord or lead is to be held 1 in (25,4 mm) from the point where the cord or lead emerges from the product and is then to be pushed back into the product. When a removable bushing which extends further than 1 in (25,4 mm) is present, it is to be removed prior to the test. When the bushing is an integral part of the cord, then the test is to be carried out by holding the bushing. The cord or lead is to be pushed back into the product in 1 in (25,4 mm) increments until the cord buckles or the force to push the cord into the product exceeds 6 lbf (26,7 N). The supply cord or lead within the product is to be manipulated to determine compliance.

S.5.2.3 Electrical tests

S.5.2.3.1 General

S.5.2.3.2 *Impulse withstand voltage* test (*type test, sample test*)

S.5.2.3.3 Alternative to *impulse withstand voltage* test (*type test, sample test*)

S.5.2.3.4 AC or DC voltage test (*type test, routine test*)

S.5.2.3.4.1 Purpose of test

S.5.2.3.4.2 Value and type of test voltage

Addition to 5.2.3.4.2;

The values of test voltage are determined from Table S.19. If the test voltage is applied to evaluate *enhanced protection*, then the value of the test voltage must be in accordance with 5.2.3.4.2.

Table S.19 – AC or DC voltage test voltages

Voltage rating, V (RMS) or DC	**Test voltage** (RMS) [a]
0 to 600 [b,c]	1 000 V + (2 x nominal voltage rating) [b,c]
601 to 1 500	2 000 V + (2,25 x nominal voltage ratings)

[a] Alternating-current, or 1,414 times the values for direct-current.

[b] For *BDM/CDM/PDS* rated not more than 250 V and intended for use in a pollution degree 2 location, the test voltage may be reduced to 1 000 V. This reduced test voltage does not apply to any internal circuits, other than the DC bus, which operate at more than 250 V.

[c] For isolated secondary circuits rated not more than 250 V and intended for use in a pollution degree 2 location, the test voltage may be reduced to 1 000 V.

S.5.2.3.5 Partial discharge test (*type test*, *sample test*)

S.5.2.3.6 *Protective impedance* test (*type test, routine test*)

S.5.2.3.7 *Touch current* measurement test (*type test*)

S.5.2.3.8 Capacitor discharge test (*type test*)

Addition to 5.2.3.8:

Verification must only be done by *type test.*

S.5.2.3.9 Limited power source test (*type test*)

S.5.2.3.10 Temperature rise test (*type test*)

Addition to 5.2.3.10:

Open and *enclosed* type *BDM/CDM/PDS* must be tested with an assumed minimum environmental *ambient temperature* of 40 °C (104 °F) unless the *BDM/CDM/PDS* is marked for a higher or lower end use *ambient temperature*. When the *BDM/CDM/PDS* is tested in an *ambient temperature* other than the end use temperature rating, the maximum measured temperatures must be linearly extrapolated for the intended end use *ambient temperature* (for example, in a 25 °C *ambient temperature*, 15 °C would be added to each temperature measurement where the maximum intended end use *ambient temperature* is 40 °C). To determine the *ambient temperature*, several temperature sensors are to be placed at different points around the *BDM/CDM/PDS* at a distance of 3 ft to 6 ft (0,9 m to 1,8 m). The temperature sensors are to be located in the path of the cooling air of the *BDM/CDM/PDS*, and are to be protected from drafts and abnormal heat radiation. The *ambient temperature* is to be the mean of the readings of the temperatures taken at equal intervals of time during the final quarter of the duration of the test.

The rated current for *BDM/CDM/PDS* rated only in horsepower and not in current is to be as specified in Table S.29 and Clause S.204. When the *BDM/CDM/PDS* is rated in current and horsepower, and the current rating is not the same as specified in Table S.29 and Table S.30 for the rated horsepower, the load current must be the greater of the two current values. No protective devices or circuitry must *trip* during the test.

When there is only provision for the connection of bus bars to *BDM/CDM* rated at 450 A or more, copper bus bars ¼ in (6,4 mm) thick of the width specified in Table S.20 and at least 4 ft (1,2 m) in length are to be used. The *clearance* and *creepage distances* between multiple bus bars is to be ¼ in (6,4 mm) with no intentional wider *clearance* and *creepage distances* except as required at the individual terminals of the *BDM/CDM/PDS*.

Table S.20 – Width of copper bus bars

Product ratings A	Bus bars per terminal	Width of bus bars	
		in	(mm)
450 to 600	1	2	(51)
601 to 1 000	1	3	(76)
1 001 to 1 200	1	4	(102)
1 201 to 1 600	2	3	(76)
1 601 to 2 000	2	4	(102)
2 001 to 2 500	2	5	(127)
	4	2-1/2	(64)
2 501 to 3 000	3	5	(127)
	4	4	(102)

Wire size for the test must be the smallest size having an ampacity of at least 125 % of the test current. See Table S.10 for wire size ampacities.

The thermocouple method for temperature measurement as specified in Table 17 consists of the determination of temperature by use of a potentiometer type instrument and thermocouples that are applied to the hottest *accessible part*s. The thermocouples are to be made of wires not larger than 24 AWG (0,21 mm^2) and not smaller than 30 AWG (0,05 mm^2). The thermocouples and related instruments are to be accurate and calibrated in accordance with standard laboratory practice. The thermocouple wire is to conform with the requirements specified in the Tolerances on Initial Values of EMF versus Temperature tables (Table 1 through Table 3) of ANSI/ASTM E230/E230M:2017.

The maximum junction temperature of power switching semiconductors, as specified by the semiconductor manufacturer, must not be exceeded during the temperature test. To determine the junction temperature, reference temperatures (case, tab, heat sink, or similar parts) are to be measured and the junction temperature is to be calculated based on the semiconductor manufacturer's power dissipation and thermal resistance data.

Additional subclauses to 5.2.3*:*

S.5.2.3.200 Production-line AC or DC voltage- test (*routine test*)

BDM/CDM/PDS provided with a power-supply cord with an attachment plug for connection to a nominal 120 V or higher voltage circuit must withstand without *electrical breakdown*, as a routine production-line test, the application of an alternating-current potential at a frequency within the range of 40 Hz to 70 Hz or a direct-current potential between the primary wiring, including connected *component*s, and dead metal *accessible parts* that are likely to become energized.

The production-line test must be in accordance with either conditions A or B of Table S.21.

Table S.21 – Production-line test conditions

***BDM/CDM/PDS* rating** V	**Condition A**			**Condition B**		
	Potential V AC	**Potential** V DC	**Time** s	**Potential** V AC	**Potential** V DC	**Time** s
250 or less	1 000	1 400	60	1 200	1 700	1
More than 250	1 000 + 2 × U^{a}	1 400 + 2,8 × U^{a}	60	1 200 + 2,4 × U^{a}	1 700 + 3,4 × U^{a}	1

[a] Maximum marked voltage.

The test potential can be gradually increased to the required value but the full value is to be applied for 1 s or 1 min as required.

The *BDM/CDM/PDS* can be at normal operating temperature, at room temperature, or at any intermediate temperature for the test.

The test must be conducted when the *BDM/CDM/PDS* is fully assembled. It is not intended that the *BDM/CDM/PDS* be unwired, modified, or disassembled for the test.

a) A part, such as a snap *cover* or friction-fit knob that would interfere with performance of the test need not be in place.
b) The test can be performed before final assembly, if the test represents that for the completed *BDM/CDM/PDS*. Any *component* not included must not affect the results with respect to determination of possible risk of electric shock resulting from miswiring, defective *component*, insufficient *clearance* and *creepage distances*, and the like.

Solid-state and similar *components* that might be damaged by a secondary effect of the test can be short-circuited by means of a temporary electrical jumper or the test can be conducted without the *component* electrically connected, providing the wiring and terminal *clearance* and *creepage distances* are maintained.

The test equipment must have a means of indicating the test potential, an audible or visual indicator of *electrical breakdown*, and, for automated or station-type operations, either a manually reset device to restore the *BDM/CDM/PDS* after *electrical breakdown* or an automatic-reject feature for any unacceptable unit. When an alternating-current test potential is applied, the test equipment must include a transformer having an essentially sinusoidal output.

When the test equipment is adjusted to produce the specified voltage, and a resistance of 120 000 Ω is connected across the output, the test equipment is to indicate an unacceptable performance within 0,5 s. A resistance of more than 120 000 Ω can be used to produce an indication of unacceptable performance when the manufacturer elects to use a tester having higher sensitivity.

When the rated output of the test equipment is less than 500 VA, the equipment must include a voltmeter in the output circuit to directly indicate the applied test potential.

When the rated output of the test equipment is 500 VA or more, the test potential can be indicated by:

c) a voltmeter in the primary circuit or in a tertiary winding circuit,
d) a selector switch marked to indicate the test potential, or
e) in the case of equipment having a single test-potential output, a marking in a readily visible location to indicate the test potential.

If an indicating voltmeter is not used, the test equipment must include a visual means, such as an indicator lamp, to indicate that the test voltage is present at the test-equipment output.

Other test equipment can be used if found to accomplish the intended factory control.

For the test, either a sufficient number of control devices are to be closed or separate applications of the test potential made, that all parts of the primary circuit are tested.

S.5.2.3.201 Production-line grounding-continuity test (*routine test*)

BDM/CDM/PDS that has an attachment plug or a power-supply cord with an attachment plug must be tested, as a routine production-line test, to determine that grounding continuity is provided between the grounding blade or pin of the attachment plug and the dead metal *accessible parts* that are likely to become energized.

Only a single test need be conducted if the metal *accessible part* selected is conductively connected to all other metal *accessible parts*.

Any indicating device (an ohmmeter, a battery and buzzer combination, or the like) can be used to determine compliance with the grounding continuity requirement.

S.5.2.3.202 Production-line polarization-continuity test – Cord and plug connected *BDM/CDM/PDS* (*routine test*)

BDM/CDM/PDS provided with a grounding type attachment plug must maintain electrical continuity between the grounding blade of the attachment plug and all *accessible part*s and must be verified as a routine production-line test. The continuity must be determined through the use of an electrical test.

S.5.2.3.203 Clamped joint test

With respect to Clause S.200, a clamped joint between two insulators is to be tested using two samples.

a) The first sample is to have the clamped joint opened up to produce a space 1/8 in (3,2 mm) wide. This is accomplished by loosening the clamping means or by drilling a 1/8 in (3,2 mm) diameter hole at the joint between the insulators at a point of minimum *clearance* and *creepage distance* between the metal parts on the opposite sides of the joint. The drilled hole must not decrease *clearance* and *creepage distances* between the opposite polarity parts as measured through the crack between the insulators. The 50 Hz to 60 Hz dielectric breakdown voltage through this hole is then determined by applying a gradually increasing voltage (500 V/s) until breakdown occurs.
b) The second sample with the clamped joint intact is to be subjected to a gradually increasing 50 Hz or 60 Hz voltage until 110 % of the breakdown voltage of S.5.2.3.203 a) has been reached. When the breakdown voltage of S.5.2.3.203 a) is less than 4 600 V RMS, the voltage applied to the second sample is to be further increased to 5 000 V RMS and held for 1 s. The clamped joint meets the intent of the requirement when there is no dielectric breakdown of the second sample.

S.5.2.4 *Abnormal operation* and simulated faults tests

S.5.2.4.1 General

Addition to 5.2.4.1:

The normative text of 5.2.4.1 items a), b) and c) does not apply. The informative note in item a) may be useful.

For the method in 5.2.4.1 item a) with respect to only the short-circuit test in 5.2.4.5, any model can serve as the representative model from a series that uses *solid state short-circuit protection* circuitry for compliance with this test when the representative model complies with S.4.3.2.2.

The criteria for samples to test for a *BDM/CDM* series that uses fuses or circuit breakers for compliance with this test is based on comparing the fuse or circuit breaker ratings to the Silicon Controlled Rectifier (SCR) or transistor output device ratings for each model within the series (specific ratings to evaluate are the I^2t and I_p values).

Additional subclauses to 5.2.4.1:

S.5.2.4.1.200 Earthing

The *BDM/CDM* must be connected to earth by means of a wire sized as noted in S.4.4.4.3.1, and in accordance with one of the following:

a) the earthing wire must be connected between the *enclosure* and earth, with the main input earth connection removed; or

b) the earthing wire must be connected between the *enclosure* and the main input power terminal judged least at risk of arcing to earth, with the main input earth connection removed. For 3-phase *BDM/CDM*, the main input power terminal judged least at risk of arcing to earth is the L2 terminal.

S.5.2.4.1.201 Branch-circuit protection

Branch-circuit protection must comply with the following requirements.

a) *BDM/CDM* must always be tested with fuses, circuit breakers, and type E combination motor controllers unless the *BDM/CDM* is marked to identify that branch-circuit short-circuit protection must be provided in compliance with one of the following:
   1) by fuses only (either semiconductor or non-semiconductor types), then testing with circuit breakers and Type E combination motor controllers is not required;
   2) by fuses (either semiconductor or non-semiconductor types) or circuit breakers only, then testing with Type E combination motor controllers is not required;
   3) by fuses (either semiconductor or non-semiconductor types) or type E combination motor controllers only, then testing with circuit breakers is not required;
   4) by circuit breakers only, then testing with fuses and type E combination motor controllers is not required.

b) The *overcurrent* protective device used for this test must be suitable for branch-circuit protection in accordance with the US National Electrical Code, NFPA 70 (fuses must comply with the series of UL 248 standards, circuit breakers must comply with UL 489, and type E combination motor controllers must comply with UL 508) and must be in accordance with the marking of the *BDM/CDM* specified in S.6.3.9.6. When the *BDM/CDM* is marked with a high fault current rating, the *overcurrent* protective device must also comply with S.5.2.4.1.202.

c) Testing with non-semiconductor types fuses must not be used in lieu of testing with circuit breakers (either inverse-time or instantaneous *trip* types) or type E combination motor controllers unless it can be shown that the let-through energy (I^2t) and peak let-through current (I_p) of the required inverse-time current-limiting circuit breaker and type E combination motor controller will be less than that of the non-semiconductor type fuses with which the *BDM/CDM* has been tested; or if the *BDM/CDM/PDS* under test is provided with solid-state short-circuit protection circuitry per S.4.3.2.2 and it can be shown by test that this circuitry operates prior to the branch-circuit protection operating.

d) Testing with semiconductor type fuses must not be used in lieu of testing with circuit breakers (either inverse-time or instantaneous *trip* types) or type E combination motor controllers.

e) Even though the operation of solid state short-circuit protection circuitry may serve as the ultimate result to discontinue the short-circuit test (see 5.2.4.5), the presence of this circuitry must not replace the requirement for the fuses, breakers or type E combination motor controllers.

f) Non-semiconductor fuse types can be rated any class that is evaluated for branch-circuit protection and must have a voltage rating at least equal to the input voltage rating of the *BDM/CDM.* These fuses must have a current rating that is one of the following standard values: 1, 3, 6, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 601, 700, 800, 1 000, 1 200, 1 600, 2 000, 2 500, 3 000, 4 000, 5 000 or 6 000 A, and must comply with one of the following:

   1) for *BDM/CDM* with rated full-load output motor currents of 600 A or less, the current rating of the fuses must be 4 times the maximum full-load motor output current rating;

   2) for *BDM/CDM* with rated full-load motor output currents of more than 600 A, the current rating of the fuses must be 3 times the maximum full-load motor output current rating;

   3) for a *BDM/CDM* of any full-load motor output current rating, the current rating of the fuse can be less than that specified in a) or b) above when the *BDM/CDM* is marked in accordance with S.6.3.9.6.1.

   When the calculated value of the fuse is between two standard ratings, the nearest standard rating less than the calculated value must apply.

g) Semiconductor fuse types must have a voltage rating at least equal to the input voltage rating of the *BDM/CDM* and can have any current rating. *BDM/CDM* using semiconductor fuse types must be marked in accordance with S.6.3.9.6.1.

h) Inverse-time circuit breakers must have a voltage rating at least equal to the voltage rating of the *BDM/CDM.* These breakers must have a current rating that is one of the following standard values: 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 700, 800, 1 000, 1 200, 1 600, 2 000, 2 500, 3 000, 4 000, 5 000 or 6 000 A, and that complies with one of the following:

   1) for *BDM/CDM* with rated full-load motor output currents of 100 A or less, the current rating of the breaker must be 4 times the maximum full-load motor output current rating; or

   2) for *BDM/CDM* with rated full-load motor output currents of more than 100 A, the current rating of the breaker must be 3 times the maximum full-load motor output current rating; or

   3) for *BDM/CDM* of any full-load motor output current rating, the current rating of the breaker is not prohibited from being less than that specified in a) or b) above when the *BDM/CDM* is marked in accordance with S.6.3.9.6.1.

   When the calculated value of the circuit breaker is between two standard ratings, the nearest standard rating less than the calculated value must apply. When the calculated value of the breaker is less than 15 A, a breaker rated 15 A must be used.

i) Instantaneous *trip* type circuit breakers must have a voltage rating at least equal to the input voltage rating of the *BDM/CDM*, and can have any current rating, when the *BDM/CDM* is marked in accordance with S.6.3.9.6.1.

j) A *BDM/CDM* utilizing non-semiconductor type fuses or inverse-time type circuit breakers sized, in accordance with S.5.2.4.1.201 f)1), S.5.2.4.1.201 f)2), S.5.2.4.1.201 h)1), or S.5.2.4.1.201 h)2), require no marking to indicate the manufacturer, model number or rating of the fuse or breaker.

k) Type E combination motor controllers are rated in volts and horsepower. To determine the current rating of the type E combination motor controller, refer to Table S.29 and read the full load current rating at the intersection of the appropriate voltage and phase columns and the applicable horsepower row. If the overload setting of the type E combination motor controller is adjustable, the full load current rating of the type E combination motor controller is defined as the maximum current setting to which the controller may be adjusted.

l) The full load current rating of the type E combination motor controller must not be less than the rated input current of the *BDM/CDM* controller.

m) When conducting the short-circuit tests with a type E combination motor controller, the tests are to be conducted with the controller at its maximum settings.

n) The short-circuit interrupting rating of the fuse, the inverse-time circuit breaker or the type E combination motor controller must not be less than the short-circuit rating of the *BDM/CDM* controller.

S.5.2.4.1.202 Input/output wiring connection

These requirements supersede the requirements to input/output wiring found in all subclauses of 5.2.4.

Each *BDM/CDM* is to be tested with 4 ft (1,2 m) of wire, or less, attached to each input and output terminal. The input/output test wiring is not prohibited from exceeding 4 ft (1,2 m) in length when the wiring is in the test circuit during its calibration.

The wire size of the input and output wiring must be in accordance with Table S.10 with the required ampacity of the wiring being based on the marked wire temperature rating (either 60 °C or 75 °C) and each of the following:

a) the main input power wiring must be sized for 125 % of the rated full-load output motor current;
b) all other input wiring must be sized for 100 % of the maximum intended full-load current;
c) the main output power wiring must be sized for 125 % of the rated full-load current or must be sized for 125 % of the full-load output motor current specified in Table S.29 or Table S.30, based on the rated horsepower rating; and
d) all other output wiring must be sized for 100 % of the maximum intended full-load current.

The type of wire *insulation* must be T or TW for 60 °C wiring and must be THW or THWN for 75 °C wiring.

For *BDM/CDM* rated more than 200 hp (150 kW), the main input/output power connections must be in accordance with the above requirements, or may be made with bus bars equivalent in cross-sectional area to the required wiring. The bus bars can be in the test circuit during its calibration.

Input and output wiring may then be routed through 10 in to 12 in (250 mm to 305 mm) lengths of conduit installed on the *enclosure*. If conduit is not used, then the wire must be routed through a bushing appropriate for the size of the conductors.

The ends of the conduit, the bushing opening, or the openings around the bus bars are to be plugged with surgical cotton.

S.5.2.4.1.203 Test sequence

The following requirements are applicable to the output short-circuit test and breakdown of *component* test, and are in addition to the requirements of 5.2.4.5 and 5.2.4.10.3.

If the test is terminated by the operation of a *electronic power output short-circuit protection circuitry,* this circuitry must be subjected to the requirements in 5.2.4.7. If the solid state short-circuit protection circuitry is not subjected the requirements in 5.2.4.7, that circuitry must be defeated prior to the test.

If the test is terminated by the opening of a *short-circuit protective device*, this device must

a) be a fuse that complies with the UL 248 series of standards for fuses,
b) be a circuit breaker that complies with UL 489, or
c) be a self-protected combination motor controller that complies with UL 60947-4-1.

An open-circuit failure of a semiconductor device is permitted for the termination of the test.

S.5.2.4.2 Supply voltage, current and frequency

Addition to 5.2.4.2:

The breakdown of *component* and short-circuit tests must be conducted at the test values in accordance with Table 36. The values in Table 36 are considered the standard fault current values. When assigned a short-circuit rating higher than the Standard fault current test value, the *BDM/CDM* must also comply with a) and b). The circuit capability for all of the tests must be verified in accordance with the calibration of short-circuit test circuit, S.5.2.4.2.200.

a) A *BDM/CDM* series with an assigned short-circuit rating higher than the standard fault current test value shown in Table 36 must comply with the short-circuit test requirements of S.5.2.4.2 for the standard fault currents and the short-circuit test – high fault currents, S.5.2.4.2.202.
b) A *BDM/CDM* series with an assigned short-circuit rating higher than the standard fault current test value shown in Table 36 must comply with the breakdown of component test requirements of S.5.2.4.2 at the standard fault current and the breakdown of component test – high fault currents, S.5.2.4.2.202.

A *BDM/CDM* series is in compliance with the short-circuit test – high fault currents, S.5.2.4.2.202, without additional testing when

c) the *BDM/CDM* series uses solid state short-circuit protection circuitry for compliance with the standard fault current short-circuit test, and
d) the solid state short-circuit protection circuitry is used in accordance with S.4.3.2.2.

Where circuit analysis demonstrates that the available short-circuit energy (based on the marked short-circuit rating) has no greater impact on the results of the breakdown of *component*s testing than a lower available short-circuit energy, the breakdown of *component* test may be conducted at the lower energy level.

The circuit analysis according to 4.2 must consider the following:

- bursting I^2t of conductors and *components*;
- identification of fault current path in the *BDM/CDM/PDS*;
- possibility and extent of cascading failures;
- nature of failure with respect to physical location (e.g. proximity to other critical *components*, barriers, *clearance*s, *creepage distance*s, vent openings);
- identification of all energy sources (*mains supply*, capacitors, batteries, motor, etc.) in the circuit;
- for *mains supply*, consider power circuit configuration and grounding (wye, delta, IT, etc.);
- *enclosure* (size, material, structure, openings, etc.);
- types and ratings of *SCPD* specified to be used with the *BDM/CDM/PDS*;
- specified linearity of current limiting *components* (external & internal) with respect to available fault current;
- effect of multiple ratings of the *PDS* (relationship of power rating and voltage);
- variation in *components* within family of *BDM/CDM*;
- maximum variation of *mains supply* impedance, frequency, voltage with respect to specified/published product applications (use of transformer, etc.);
- testing may be necessary to validate portions of the circuit analysis.

Additional subclauses to 5.2.4.2:

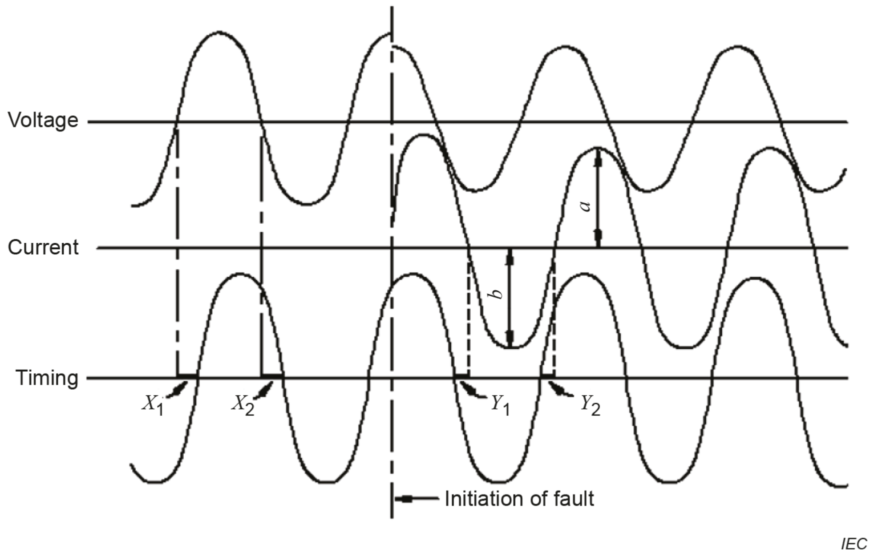
S.5.2.4.2.200 Calibration of short-circuit test circuits 10 000 A or less

For an AC circuit intended to deliver 10 000 A or less, the current is to be determined in accordance with one of the following.

a) For a 3-phase test circuit, the current is to be determined by averaging the RMS values of the first complete cycle of current in each of the three phases.

b) For a single phase test circuit, the current is to be the RMS value of the first complete cycle (see Figure S.2) when the circuit is closed to produce symmetrical current waveform. The DC component is not to be added to the value obtained when measured as illustrated. In order to obtain the required symmetrical waveform of a single phase circuit, controlled closing is most often used although random closing methods are not prohibited from being used.

c) For a single or 3-phase test circuit, an analytical evaluation that suitably demonstrates the available current can be used.



Current = [(a+b)/2] (RMS calibration of instrument element)

Figure S.2 – Determination of current for circuits of 10 000 A and less

S.5.2.4.2.201 Calibration of short-circuit test circuits more than 10 000 A

For an AC circuit intended to deliver more than 10 000 A, the current is to be determined in accordance with one of the following:

a) in accordance with the requirements in S.5.2.4.2.201, instrumentation used to measure these test circuits of more than 10 000 A is to comply with the requirements in S.5.2.4.2.201; or

b) for a single or 3-phase test circuit, an analytical evaluation that suitably demonstrates the available current can be used.

The RMS symmetrical current is to be determined, with the supply terminals short-circuited by measuring the AC component of the wave at an instant 1/2 cycle – on the basis of the test frequency timing wave – after the initiation of the short-circuit. The current is to be calculated in accordance with Figure D.1 of ANSI/IEEE C37.90-2005.

For a 3-phase test circuit, the RMS symmetrical current is to be the average of the currents in the three phases. The RMS symmetrical current in any one phase is not to be less than 90 % of the required test current.

The test circuit and its transients are to be such that

c) 3 cycles after initiation of the short-circuit, the symmetrical alternating component of current is not less than 90 % of the symmetrical alternating component of current at the end of the first ½ cycle, or

d) the symmetrical alternating component of current at the time at which the *overcurrent* protective device interrupts the test circuit is at least 100 % of the rating for which the controller is being tested. In 3-phase circuits, the symmetrical alternating component of current of all three phases is to be averaged.

The recovery voltage is to be at least equal to the rated voltage of the controller. The peak value of the recovery voltage within the first complete half cycle after clearing and for the next five successive peaks is to be at least equal to 1,414 times the RMS value of the rated voltage of the controller. Each of the peaks is not to be displaced by more than ±10° elec. from the peak values of the open-circuit recovery voltage – that is, the displacement of the peak from its normal position on a sinusoidal wave. The average of the instantaneous values of recovery voltage each of the first six, half cycles measured at the 45° and 135° points on the wave is to be not less than 85 % of the *RMS* value of the rated voltage of the controller. The instantaneous value of recovery voltage measured at the 45° and 135° points of each of the first six, half cycles is in no case to be less than 75 % of the *RMS* value of the rated voltage of the controller.

When there is no attenuation or phase displacement of the first full cycle of the recovery voltage wave when compared with the open-circuit secondary voltage wave before current flow in a circuit that employs secondary closing, the detailed measurement of recovery voltage characteristics as indicated above is not required.

The galvanometers in a magnetic oscillograph employed for recording voltage and current during circuit calibration and while testing are to be of a type having a flat (±5 %) frequency response from 50 Hz to 1 200 Hz. For fast acting fuses, current limiters, or motor-short-circuit protectors, a galvanometer is often required to have a flat frequency response from 50 Hz to 9 000 Hz or an oscilloscope is required to be used to obtain accurate values of peak current, (I_p), and energy let-through, (I^2t).

Galvanometers are to be calibrated as follows.

e) When a shunt is used to determine the circuit characteristics, a direct-current calibrating voltage is normally used. The voltage applied to the oscillograph galvanometer circuit is to result in a deflection of the galvanometer equivalent to that which is expected when the same galvanometer circuit is connected to the shunt and the nominal short-circuit current is flowing. The voltage is to be applied so as to result in the galvanometer deflecting in both directions. Additional calibrations are to be made using 50 % and 150 % of the voltage used to obtain the deflection indicated above, except that when the anticipated maximum deflection is less than 150 %, such as a symmetrically closed single-phase circuit, any other usable calibration point is to be chosen. The sensitivity of the galvanometer circuit in volts per inch (or millimeter) is to be determined from the deflection measured in each case, and the results of the six trials averaged. The peak amperes per inch (or millimeter) is obtained by dividing the sensitivity by the resistance of the shunt. This multiplying factor is to be used for the determination of the RMS current as described previously in S.5.2.4.2.201.

f) A 50 Hz or 60 Hz sine-wave potential can be used for calibrating the galvanometer circuit, using the same general method described in e). The resulting factor is to be multiplied by 1,414.

g) When a current transformer is used to determine the circuit characteristics, an alternating current is to be used to calibrate the galvanometer circuit. The value of current applied to the galvanometer circuit is to result in a deflection of the galvanometer equivalent to that which is expected when the same galvanometer is connected to the secondary of the current transformer and nominal short-circuit current is flowing in the primary. Additional calibrations are to be made at 50 % and 150 % of the current used to obtain the deflection indicated above except that when the anticipated maximum deflection is less than 150 %, such as in a symmetrically closed single-phase circuit, any other usable calibration point is to be chosen. The sensitivity of the galvanometer circuit in RMS amperes per inch (or millimeter) is to be determined in each case and the results averaged. The average sensitivity is to be multiplied by the current-transformer ratio and by 1,414 to obtain peak amperes per inch. This constant is to be used for the determination of the RMS current as described previously in S.5.2.4.2.201.

h) All the galvanometer elements employed are to line-up properly in the oscillograph, or the displacement differences are to be noted and used as required.

The sensitivity of the galvanometers and the recording speed are to be such that the values of voltage, current, and power factor are accurately determined. The recording speed is to be at least 60 in (1,5 m) per second.

With the test circuit adjusted to provide the specified values of voltage and current and with a noninductive (coaxial) shunt that has been found to provide the intended function for use as a reference connected into the circuit, the following tests are to be conducted to verify the accuracy of the manufacturer's instrumentation.

i) With the secondary open-circuited, the transformer is to be energized and the voltage at the test terminals observed to see when rectification is occurring making the circuit unusable for test purposes because the voltage and current are not sinusoidal. Six random closings are to be made to demonstrate that residual flux in the transformer core does not result in rectification. When testing is done by closing the secondary circuit, this check can be omitted when testing is not commenced before the transformer has been energized for 2 s, or longer, and when an investigation of the test equipment shows that a longer time is required.

j) With the test terminals connected together by means of a copper bar, a single-phase circuit is to be closed as nearly as possible at the moment that produces a current wave with maximum offset. The short-circuit current and voltage are to be recorded. The primary voltage is to be recorded when primary closing is used. The current measured by the reference shunt is to be within 5 % of that measured using the manufacturer's instrumentation and there is to be no measurable variation in phase relationship between the traces of the same current. Controlled closing is not required for polyphase circuits.

When the verification of the accuracy of the manufacturer's instrumentation is completed, the reference coaxial shunt is to be removed from the circuit. The reference coaxial shunt is not to be used during the final calibration of the test circuit nor during the testing of controllers.

S.5.2.4.2.202 Short-circuit test and breakdown of *component* test – high fault currents

When any models within a *BDM/CDM* series are intended to be rated with high fault current values in excess of the standard current values required by Table 36, then they must comply with both a) and b) below, or must comply with S.5.2.4.2.202.

a) the *BDM/CDM* series uses solid state short-circuit protection circuitry for compliance with the short-circuit test, 5.2.4.5 and S.5.2.4.5; and

b) the solid state short-circuit protection circuitry is used in accordance with S.4.3.2.2.

One representative model from those intended to be rated with high fault current values must be used for testing. This representative model must be subjected to only one high fault current short-circuit test.

The criteria for samples to test for a *BDM/CDM* series that uses fuses for compliance with this test is based on comparing the fuse ratings to the silicon controlled rectifier (SCR) or transistor output device ratings for each model within the series (specific ratings to evaluate are the I^2t and I_p values).

The high fault current values for which a *BDM/CDM* can be tested are not required to be one of the same values detailed in Table 36.

The requirements for conducting the high fault current short-circuit test must be in accordance with 5.2.4.5 except for the following differences.

c) For *BDM/CDM* rated over 10 000 A, the branch-circuit short-circuit protection fuses must be limited to high-interrupting capacity, current limiting types such as class CC, CF, G, J, L, R, T, etc.

d) For *BDM/CDM* rated 50 hp (37 kW) or less and tested at 10 000 A, the branch-circuit short-circuit protection fuses can be class H or K.

e) A *BDM/CDM* that is intended to be used with class RK1 or RK5 fuses must be tested with fuses having I^2t and Ip characteristics for class RK5 fuses. All references to class R fuses are intended to mean fuses with energy let-through (I^2t) characteristics of class RK5 fuses.

f) For noncombination controllers, the circuit breaker to be used is to be from commercially available units of the moulded-case type having the same characteristics with respect to opening time and without current-limiting features.

g) For circuit breakers with current limiters provided as part of the controller, the current limiter must have a peak let-through current and a clearing I^2t not less than the maximum value established for the current limiter intended to be used with the controller being tested, when tested on a single-phase circuit.

h) A Class CC, CF, G, J, L, R, or T fuse, or motor short-circuit protector must have a peak let-through current and clearing I^2t not less than the maximum value established for the fuse (see the UL 248 series of standards for fuses), or motor short-circuit protector rating that is intended to be used with the controller being tested, when tested on a single-phase circuit. For a fuse with I_p and I^2t limits established for several different short-circuit current levels, the test fuse is to have at least the maximum values of the current corresponding to the marked short-circuit-withstand current of the controller.

i) A test limiter is not prohibited from being used in place of the fuses specified in items c), d), e), and h) above.

To obtain the required values specified in h) and i) above, a fuse, current limiter, or motor short-circuit protector larger than that specified for use with the device being tested can be used; or a commercially available test fuse designed and calibrated to exhibit I^2t and I_p characteristics at least equal to the maximum limits for the fuse, current limiter, or motor short-circuit protector rating. The let-through characteristics are to be determined in accordance with the following requirements.

Fuses, current limiters, or motor short-circuit protectors used for tests are to be from a batch from which two samples have been tested. The value of the I_p and I^2t determined for the two samples is to be equal to or greater than the required values. These determinations are to be made in accordance with the following requirements.

Figure S.3 is typical of oscillograms obtained during the test of a fuse, current limiter, or motor short-circuit protectors on an alternating-current circuit; and represents a circuit that opened before the current reached its first major peak. The peak let-through current I_p is to be determined as illustrated.

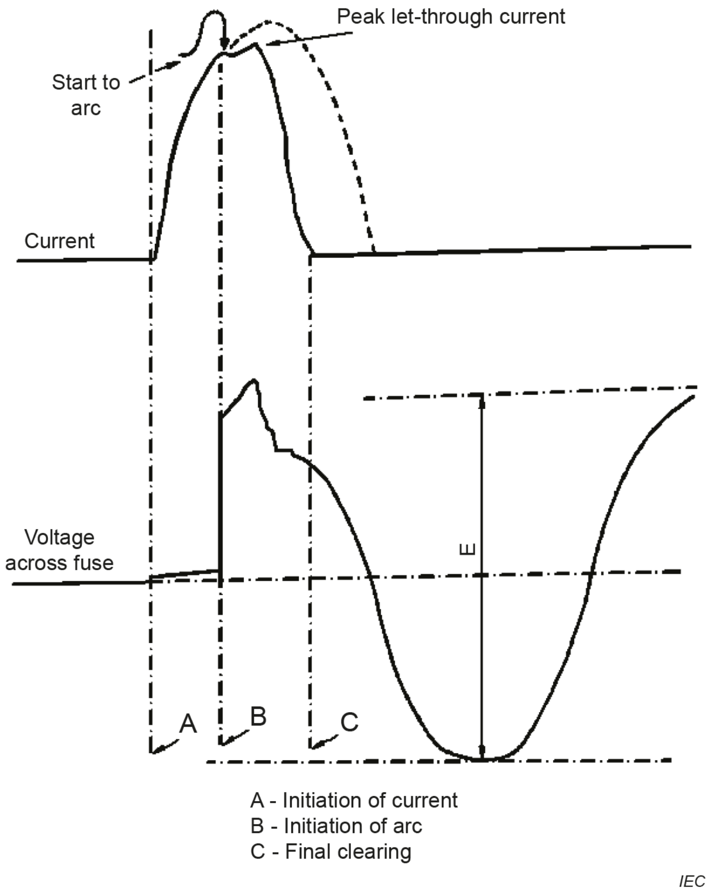


Figure S.3 – Peak let-through current

The let-through energy (I^2t) is to be determined from an oscillogram showing a current trace during the interruption of the circuit by the fuse, current limiter, or motor short-circuit protectors. The determination is to be made by the application of Simpson's rule illustrated in Figure S.4 or the use of an integrating planimeter.

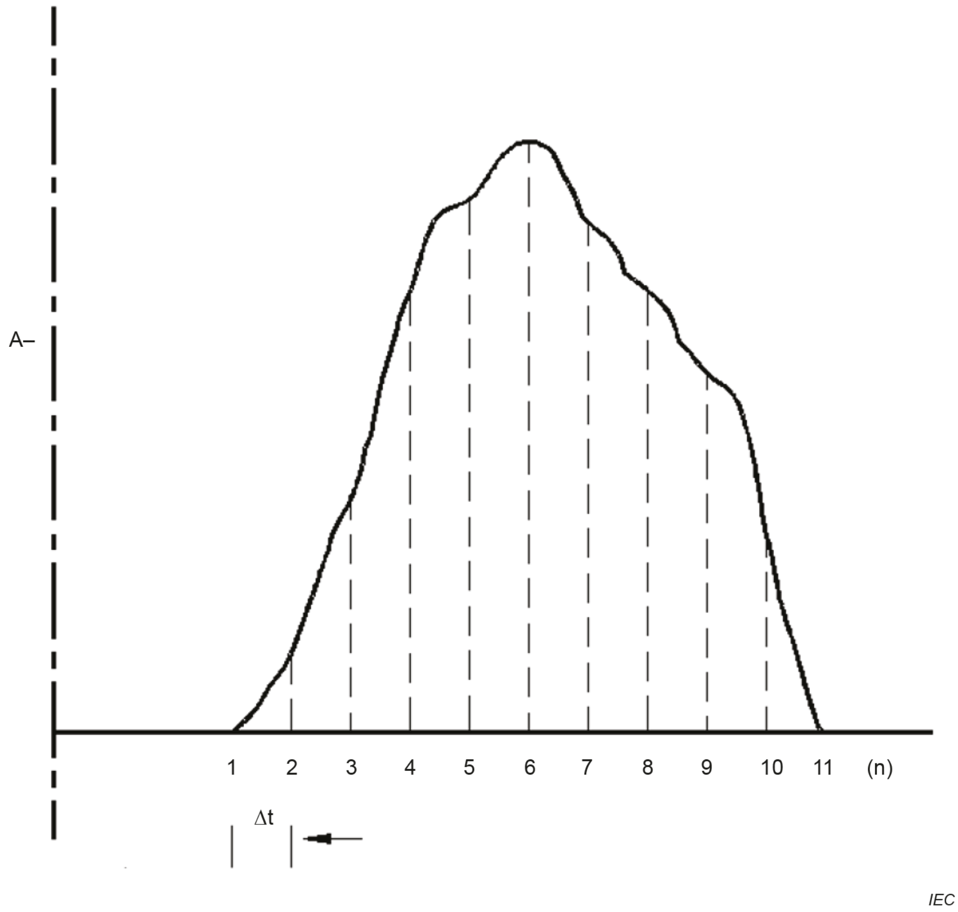


Figure S.4 – Application of Simpson's rule to fuse current oscillogram to obtain let-through I^2t

The time base in degrees-per-inch (degrees/cm) is to be determined by averaging the distance, between zero-line crossover points of the voltage wave or a timing wave, in which the fuse-current race is most nearly centered.

S.5.2.4.3 Acceptance criteria

Addition to 5.2.4.3:

It is not required to monitor the voltages of accessible *DVC As circuits* if the *PDS* complies with the AC or DC voltage requirements in accordance with 5.2.3.4 at the conclusion of the test.

S.5.2.4.4 *Protective equipotential bonding* short-circuit withstand test (*type test*)

S.5.2.4.5 Output short-circuit test (*type test*)

S.5.2.4.6 *Electronic motor overload protection* test (*type test*)

S.5.2.4.6.1 General requirements

S.5.2.4.6.2 Test set-up

S.5.2.4.6.3 Acceptance criteria

S.5.2.4.6.4 *Electronic motor overload protection* test (*type test*)

S.5.2.4.6.5 Electronic motor *thermal memory retention trip* test (*type test*)

S.5.2.4.6.6 Electronic motor *thermal memory retention* loss of power test (*type test*)

S.5.2.4.6.7 Electronic motor thermal speed sensitivity test (type test)

Addition to 5.2.4.6.7 by the following.

With respect to 5.2.4.6.7, items b) and item e), output frequency must apply to *BDM/CDM* with AC rated motor power output and output voltage must apply to *BDM/CDM* with DC rated motor power output.

S.5.2.4.7 Circuit functionality evaluation test (*type test*, *routine test, sample test*)

S.5.2.4.8 Current limiting test (*type test*)

S.5.2.4.9 Output overload test (*type test*)

S.5.2.4.10 Breakdown of *component* test (*type test*)

S.5.2.4.11 PWB short-circuit test (*type test*)

Addition to 5.2.4.11:

The outer *enclosure* of the *PDS* and any exposed dead metal parts, normally intended to be earthed, are disconnected from earth and are to be connected through a 10 AWG (5,3 mm^2) solid copper wire 4 ft to 6 ft (1,22 m to 1,83 m) long to the supply circuit pole least likely to arc to earth (usually the center terminal for three-phase *BDM/CDM/PDS*).

When the circuit is interrupted by the opening of a *component* other than the *overcurrent* protective device, or of a printed wiring board (PWB) trace, the test is to be repeated to demonstrate equivalent results.

S.5.2.4.12 Loss of phase test (*type test*)

S.5.2.4.13 Cooling failure test (*type test*)

S.5.2.4.13.1 General and acceptance criteria

S.5.2.4.13.2 Inoperative blower motor test (*type test*)

Addition to 5.2.4.13.2:

Where an electrical *single-fault condition* could result in the loss of operation of one or more blowers, that fault will be applied and the blower rotation will not be prevented. This is in addition to testing with physically preventing the rotation of individual blowers.

Additional subclauses to 5.2.4:

S.5.2.4.200 Contactor overload test

A contactor having the coil circuit interlocked or sequenced such that, under normal operating conditions, the contactor does not make or break load current is to be subjected to five close-open operations, with the interlocking or sequencing defeated. The test current must be the current the contactor carries when the *BDM/CDM/PDS* is delivering the maximum overload current. The maximum overload current is defined as the maximum current the *BDM/CDM/PDS* is capable of delivering for a time of one cycle of mains frequency. The duration of current flow when the contactor is closed must be at least 4 cycles and the maximum time between cycles must be 240 s. Power factor or time constant for the load must be representative of the power factor or time constant on the contactor circuit when in operation in the *BDM/CDM/PDS*. The test circuit voltage to the contactor must be equal to the highest voltage to which the contactor is subjected during operation in the *BDM/CDM/PDS*.

There must be no continuity across any pole of the contactor at the end of the fifth operation.

At the completion of the test, the sample must comply with the requirements of the AC or DC voltage test of 5.2.3.4.

S.5.2.4.201 *Group installation* (optional)

S.5.2.4.201.1 General

*BDM/*CDM intended for *group installation* must comply with the following requirements.

a) A *BDM/CDM* that is intended to be marked as suitable for *group installation* per S.6.3.9.6.2 must be tested in accordance with S.5.2.4.201. *BDM/CDM* s intended for *group installation* at high fault currents must be tested in accordance with S.5.2.4.201.2 to S.5.2.4.201.6. Wiring terminals of *BDM/CDM* intended for *group installation* must comply with S.5.2.4.201.1. *BDM/CDM* intended for *group installation* according to the following must be marked in accordance with S.6.3.9.6.2 and the last paragraph of S.6.3.7.4.1.

b) The requirements in S.5.2.4.201 cover the following *BDM/CDM*:

   1) *BDM/CDM* for use on circuits having available short-circuit currents at standard fault levels or at high fault levels;

   2) *BDM/CDM* protected by an inverse-time circuit breaker or non-semiconductor fuse(s) intended to provide branch-circuit protection for two or more motors, or one or more motors and other loads. The protective device(s) must be selected in accordance with S.5.2.4.201;

   3) *BDM/CDM* connected to branch-circuit conductors that have an ampacity not limited to 125 % of rated full-load input controller current or 125 % of rated full-load output motor current. The main input and output power conductors must be sized according to S.5.2.4.201;

   4) *BDM/CDM* that incorporates solid state overload protection that is subjected to the requirements in 5.2.4.7 and that complies with the electronic motor overload protection test in 5.2.4.6.4.

c) The branch-circuit protective devices must be selected in accordance with S.5.2.4.1.201, with the following additions:

   1) the branch-circuit protective devices must be either inverse time circuit breakers or non-semiconductor fuses;

   2) the current rating of the protective device is permitted to be greater than the values specified in S.5.2.4.1.201. The maximum size of the branch-circuit protective device must not exceed the ampere rating calculated from the following formula:

$$I = (9{,}6 \times A) - (2{,}2 \times FLA)$$

   where

   I is the ampere rating of the protective device;

A is the maximum wire size and is the ampacity from Table S.10 of the largest conductor size for which the device terminals have been evaluated;

FLA is the minimum motor FLA and is the smallest rated FLA (or equivalent FLA from horsepower rating per Table S.29) marked on the device.

d) The input and output wiring must be in accordance with S.5.2.4.1.202, with the following additions:

   1) the main input power conductors are permitted to be larger than those specified in S.5.2.4.1.202 a);

   2) the main output power conductors are permitted to be larger than those specified in S.5.2.4.1.202 c).

e) A wiring terminal must comply with secureness and pullout requirements with the maximum size conductor permitted by the marking specified in S.6.3.7.4.1.

S.5.2.4.201.2 Sample selection

A sample *BDM/CDM* that complies in all other respects with requirements in this document must be subjected to the tests specified in S.5.2.4.201.1. The *BDM/CDM* is to be connected in series with

a) a non-semiconductor fuse(s) or an inverse-time circuit breaker of the maximum standard rating with which the *BDM/CDM* is intended to be used, and

b) the maximum size of main input and output power conductors with which the *BDM/CDM/PDS* is intended to be used.

S.5.2.4.201.3 Short-circuit test – *Group installation* for standard fault currents

A *BDM/CDM* having short-circuit ratings at levels specified in Table 36 must comply with the requirements of 5.2.4.5 with the following additions.

a) A *BDM/CDM* controller that does not rely solely on solid-state short-circuit protection must be tested on a circuit that complies with the power factor specified in Table S.22. The circuit must be calibrated as described in the calibration of test circuits, S.5.2.4.2.200 or S.5.2.4.2.201.

b) The input and output wiring must be according to S.5.2.4.201.1.

c) The current rating and type of branch-circuit protective device(s) must be selected according to S.5.2.4.201.1.

d) The branch-circuit short-circuit protection must be marked in accordance with S.6.3.9.6.2.

Table S.22 – Power factor of test circuits for devices rated 600 V or less

Test current, amperes[a]	Power factor[b]
10 000 amperes or less	0,70 to 0,80
10 001 to 20 000	0,25 to 0,30
Greater than 20 000	0,15 to 0,20

[a] Symmetrical RMS amperes.

[b] Lower power factor circuits than specified may be used.

S.5.2.4.201.4 Short-circuit test – *Group installation* for high fault currents

A *BDM/CDM* having short-circuit ratings in excess of the levels specified in Table 36 must comply with the requirements of S.5.2.4.2.202 with the following additions.

a) The reference S.5.2.4.201.3 is added to the 5.2.4.5 reference in S.5.2.4.2.202.

b) The maximum current rating of the branch-circuit protective device(s) must be selected according to S.5.2.4.201.1. The type of the branch-circuit protective device(s) must comply with S.5.2.4.201.1.

S.5.2.4.201.5 Breakdown of *component*s test – *Group installation* for standard fault currents

A *BDM/CDM* having short-circuit ratings at the standard available levels specified in Table 36 must be tested in accordance with 5.2.4.10, with the following additional requirements.

a) The *BDM/CDM* must be connected in series with branch-circuit protective devices selected according to S.5.2.4.201.1.
b) The *BDM/CDM* must be tested with 4 feet (1,2 m) of wire, or less, attached to each input terminal and output terminal (if required). For enclosed *BDM/CDM*, the input wiring and output wiring (if required) is then to be routed through 10 in to 12 in (250 mm to 305 mm) lengths of conduit installed on the *enclosure* with the ends of the conduit plugged with surgical cotton. For an *open type BDM/CDM*, a wire mesh cage that is 1,5 times the size of the controller is usable to simulate the intended *enclosure*. The wire mesh cage must be grounded per a).
c) The input and output wiring must be according to S.5.2.4.201.1.
d) The *BDM/CDM* must be tested on a circuit that is calibrated as described in S.5.2.4.2.200. The available short-circuit current of the test circuit must be the standard fault current value according to Table 36.

S.5.2.4.201.6 Breakdown of *component*s test – *Group installation* for high fault currents

A *BDM/CDM* having short-circuit ratings in excess of the levels specified in Table 36 must comply with S.5.2.4.201.5.

A *BDM/CDM* having short-circuit ratings in excess of the levels specified in Table 36 must additionally be tested in accordance with 5.2.4.10, with the following additions:

a) S.5.2.4.201.5, a) to d), is added to the requirements of 5.2.4.10;
b) the branch-circuit protective device(s) must also comply with S.5.2.4.2.202, c) to i).

The *BDM/CDM* must be tested on a circuit that is calibrated as described in S.5.2.4.2.201. The available short-circuit current of the test circuit must be the maximum value for which the *BDM/CDM* is rated. The high fault current values for which a *BDM/CDM* can be tested are not required to be one of the same values detailed in Table 36.

S.5.2.5 Material tests

S.5.2.6 Environmental tests (*type tests*)

S.5.2.7 Hydrostatic pressure test (*type test, routine test*)

Addition to 5.2.7:

For the *type test*, the pressure must be increased at a gradual rate until a pressure relief mechanism operates or until 5 times the maximum pressure rating is attained. If a pressure relief mechanism does not operate, the pressure must be maintained at 5 times the maximum pressure rating for 1 min. There must be no leakage of coolant during the test, other than from a pressure relief mechanism, during the *type test*. Leakage from a pressure relief mechanism must not occur in the electrical compartment. After the *type test*, the AC or DC voltage test of 5.2.3.4 must be performed.

S.6 Information and marking requirements

S.6.1 General

Addition to 6.1:

Every product supplied, even if more than one is provided to a single customer, must be provided with all required information.

The use of international symbols is not required unless specifically identified.

S.6.2 Information for selection

S.6.2.1 General

Addition to 6.2.1:

BDM/CDM/PDS must be plainly marked with the *enclosure* type rating for enclosed *BDM/CDM/PDS*. Marking of the IP rating is not required.

With reference to S.4.12.201.2, a Type 4X *enclosure* intended for indoor use only must be marked

"Type 4X indoor use only"

in letters that are legible and of the same font and height.

Additional subclause to 6.2.1:

S.6.2.1.200 Class 2 circuit markings

S.6.2.1.200.1 Class 2 circuits

A Class 2 power source must be durably marked where visible after installation to indicate the class of supply and its electrical rating. A Class 2 power source not evaluated for use in wet locations must be marked

"Not for use in wet locations"

or the equivalent.

A secondary circuit intended to be supplied from a Class 2 transformer or power source in the field must be marked

"Class 2" next to the voltage rating of the device (for example, 30 Vac, Class 2),

or the equivalent.

S.6.2.1.200.2 Secondary circuits

A secondary circuit evaluated to the requirements in S.203.1.8 must be provided with installation instructions that specify the use of the isolating source and ratings of the *overcurrent* protective devices required to be installed in the field.

S.6.3 Information for installation and commissioning

S.6.3.1 General

Addition to 6.3.1:

Markings required in this document must include all of the text as specified and may also include diagrammatic representation. Text in languages other than as specified may also be provided.

S.6.3.2 Mechanical considerations

S.6.3.3 Environment

Addition to 6.3.3:

The following optional markings must only be marked on *BDM/CDM* that has been evaluated in accordance with requirements for plenum rated *BDM/CDM* in S.4.6.200:

- "Suitable for installation in a compartment handling conditioned air"; or
- "Suitable for use in other environmental air space in accordance with Section 300.22 (C) of the National Electrical Code".

S.6.3.4 Handling and mounting

S.6.3.5 *Enclosure* temperature

S.6.3.6 Open type *BDM/CDM*

S.6.3.7 Connections

S.6.3.7.1 General

S.6.3.7.2 Interconnection and wiring diagrams

Addition to 6.3.7.2:

BDM/CDM/PDS incorporating two or more separate circuits that can be connected to separate power supplies and that are intended to be connected to a common power supply must be marked

> "All circuits must have a common disconnect and be connected to the same pole of the disconnect"

or with an equivalent wording. The wiring diagram of the *BDM/CDM/PDS* must illustrate a typical connection of the various circuits connected to the common power supply.

S.6.3.7.3 Conductor (cable) selection

S.6.3.7.4 Identification and other details of *field wiring terminals*

S.6.3.7.4.1 Identification of *field wiring terminals*

Addition to 6.3.7.4.1:

When wire leads are provided, a lead intended to be connected to a grounded supply circuit must have a white or grey colour and must be readily distinguishable from other leads.

A single white terminal – in other than a single-pole device – for the connection of an ungrounded conductor must not be provided; however, two or more white terminals may be provided when:

a) it does not make any difference how phase connections are made,

b) it is obvious which terminal is intended for the connection of the grounded conductor, or

c) the phase connections are plainly indicated on a wiring diagram.

When *low-voltage BDM/CDM/PDS* or a part of *low-voltage BDM/CDM/PDS* is intended to be field wired, the *BDM/CDM/PDS* must comply with the following.

d) When intended to become only part of a class 1 circuit, the terminals must be marked accordingly.

e) When intended to become only part of a class 2 circuit wired with class 1 wire, the terminals must be marked accordingly.

f) When *low-voltage* switching or power-consuming *BDM/CDM/PDS* or a part of *BDM/CDM/PDS* is intended to become part of a class 2 circuit only, the terminals must be marked accordingly;.

g) A *low-voltage* power-supply device that includes a transformer is not required to be marked to indicate that it is acceptable for use in a class 2 circuit only.

h) *Low-voltage BDM/CDM/PDS* or a part of *BDM/CDM/PDS* that is intended for connection to either a class 1 or a class 2 circuit is not required to be marked.

A wiring terminal that is not intended to receive a conductor one size larger than that specified in S.4.11.11.2 must be marked to restrict its use to the smaller size conductor.

A control with direct-current motor ratings that does not comply with the requirements in S.4.11.11.2 must be marked with the word "WARNING" and the following or the equivalent:

> "Do not connect to a circuit supplied by a single-phase, half-wave rectifier".

A control that does not comply with the requirements in S.4.11.11.2 must be marked with the word "WARNING" and the following or the equivalent:

> "Do not connect to a circuit supplied by a single-phase rectifier of the half-wave or full-wave type."

A *field wiring terminal* of *BDM/CDM* intended for group *installation*, as described in S.5.2.4.201.1, must be marked to restrict its use to conductors that have a maximum size of that used when tested in accordance with S.5.2.4.201.1.

S.6.3.8 Commissioning

Addition to 6.3.8:

These requirements are not required in the US because they are not considered part of the specifications for certification.

S.6.3.9 Protection requirements

S.6.3.9.1 *Accessible parts* and *accessible circuits*

S.6.3.9.2 Protective class

S.6.3.9.3 *Protective equipotential bonding* circuit

S.6.3.9.4 *Touch current* or high leakage current

S.6.3.9.5 Compatibility with RCD

S.6.3.9.6 External protection means

Replacement:

S.6.3.9.6.1 Branch-circuit short-circuit protection

BDM/CDM must be marked

> "Suitable for use on a circuit capable of delivering not more than ___________ RMS symmetrical amperes, ___________ volts maximum."

The ampere rating is not to be more than the value for which the controller was tested in accordance with 5.2.4.5 and 5.2.4.10. When tested in accordance with S.5.2.4.2.202, the marking must also include the following or the equivalent:

a) "When protected by ___________ class fuses," or

b) "When protected by a circuit breaker having an interrupting rating not less than ___________ RMS symmetrical amperes, ___________ volts maximum."

BDM/CDM provided with *solid state short-circuit protection* in accordance with *solid state short-circuit protection* of S.4.3.2.2 must be marked

> "Integral *solid state short-circuit protection* does not provide branch-circuit protection. Branch-circuit protection must be provided in accordance with the National Electrical Code and any additional local codes," or the equivalent.

A *BDM/CDM* protected by fuses (either semiconductor or non-semiconductor types), circuit breakers (either inverse-time or instantaneous *trip* types), or type E combination motor controllers, sized in accordance with S.5.2.4.1.201 f) to i), k), l), or n) must be marked as noted below.

c) For non-semiconductor fuse types, the marking must include the class – when other than class H or K5 – and the voltage and current or voltage and percent of the full-load motor output current rating.

d) For semiconductor fuse types, the marking must include the fuse manufacturer and fuse model number (no fuse rating marking is required). This marking must also state that the *BDM/CDM* controller and *overcurrent* protective device must be integrated within the same overall assembly.

e) For current limiting circuit breakers, the marking must include voltage and current or voltage and percent of the full-load motor output current rating. The marking must also include the manufacturer and model number of the circuit breaker.

f) For non-current limiting inverse-time circuit breaker types, the marking must include voltage and current or voltage and percent of the full-load motor output current rating.

g) For instantaneous *trip* circuit breaker types, the marking must include the breaker manufacturer and breaker model number (no breaker rating marking is required). This marking must also state that the *BDM/CDM overcurrent* protective device must be integrated within the same overall assembly.

h) For type E combination motor controllers, the marking must include the *BDM/CDM* manufacturer, model number, rated voltage and rated HP.

S.6.3.9.6.2 Branch-circuit short-circuit protection for group *installation*

For group *installation*, *BDM/CDM* as described in S.5.2.4.201.1 must be marked with the following or the equivalent.

a) When tested using both fuses and circuit breakers of the maximum allowable size: "Suitable for motor *group installation* on a circuit capable of delivering not more than ____ RMS symmetrical amperes, ____ V max." When tested with other than class H or K5 fuses, the marking must additionally state: "When protected by class ___ fuses." When specified for a high fault short-circuit rating, the marking must additionally state: "Class ___ fuses" or "A circuit breaker having an interrupting rating not less than ___RMS symmetrical amperes, ___ V maximum."
b) When tested using only fuses rated at the maximum size specified in S.5.2.4.201.1 c)2), the marking must additionally state: "When protected by fuses" or, when tested with other than class H or K5 fuses, "When protected by class ___ fuses." When specified for a high fault short-circuit rating, "When protected by class ___ fuses."
c) When tested using branch-circuit protective devices rated less than the maximum size specified in S.5.2.4.201.1 c)2), the marking must additionally state: "When protected by (A) with a maximum rating of (B)" where:
   1) (A) is the type of *overcurrent* protective devices, either "fuses" or "a circuit breaker." When tested with other than class H or K5 fuses, "Class ___ fuses." When specified for a high fault short-circuit rating, "Class ___ fuses" or "A circuit breaker having an interrupting rating not less than ___RMS symmetrical amperes, ___ V maximum";
   2) (B) is the maximum ampere rating of the *overcurrent* protective device used for the tests in S.5.2.4.201.3 and S.5.2.4.201.5, or S.5.2.4.201.4 and S.5.2.4.201.6.

BDM/CDM provided with *solid state short-circuit protection* in accordance with S.4.3.2.2 and intended for *group installation* as described in S.5.2.4.201.1 b), must be marked in accordance with the second paragraph of S.6.3.9.6.1, or the equivalent.

S.6.3.9.6.3 Control circuit protection

BDM/CDM/PDS must comply with the following requirements for markings related to control circuit protection.

a) In accordance with S.4.11.200.1, p), when the additional wiring protection is not required due to the rating or *trip* setting of an instantaneous trip circuit breaker used as the branch-circuit *short-circuit protection*, then the *BDM/CDM* must be provided with a marking or instructions indicating the maximum wiring protective device size required by Table S.13.
b) Regarding the requirement in S.4.11.200.1, i), when a supplementary fuse is being relied upon for compliance with this requirement, then a replacement marking or instructions must be provided that includes the voltage and current rating of the fuse.
c) In accordance with the third paragraph of S.4.11.200.1, when a field installed kit is being relied upon to provide the additional wiring protection, then the *BDM/CDM* must be provided with a marking or instructions to identify this kit.
d) Regarding the requirement in the fourth paragraph of S.4.11.200.1, when a fuse (other than supplementary) is being relied upon to provide the additional wiring protection and when the fuse-holder accepts a fuse having a higher current rating than required by S.4.11.200.1, then the *BDM/CDM* must be provided with a marking or instructions identifying the maximum fuse size.

S.6.3.9.6.4 High available fault current – Damage warning

BDM/CDM intended for use on circuits having high available fault currents as indicated in S.5.2.4.2.202 must be marked with the word "WARNING" and the following or equivalent:

> "The opening of the branch-circuit protective device may be an indication that a fault current has been interrupted. To reduce the risk of fire or electric shock, current-carrying parts and other *components* of the controller should be examined and replaced if damaged. If burnout of the current element of an overload relay occurs, the complete overload relay must be replaced."

S.6.3.9.6.5 Cord-connected *BDM/CDM/PDS overcurrent* protection

When required by S.4.11.10.1, cord-connected *BDM/CDM/PDS* must be marked with the voltage and ampere rating of the required *overcurrent* protective device.

Additional subclause to 6.3.9:

S.6.3.9.200 *Enclosure* bonding

The marking required for *enclosures* that are intended for field assembly of the bonding means in accordance with S.4.4.4.2.200 must

a) be located where visible during installation, such as inside the *cover*, and
b) consist of the word "CAUTION" and the following, or the equivalent as applicable:
   - "Bonding between conduit connections is not automatic and must be provided as a part of the *installation*"; and/or
   - "Nonmetallic enclosure does not provide grounding between conduit connections. Use grounding bushings and jumper wires."

An *enclosure* of insulating material that has no means for continuity of grounding between any conduit provisions must be marked that only one conduit is to be connected to the *enclosure*.

S.6.4 Information for intended use

S.6.4.1 General

Addition to 6.4.1:

For certification purposes, identification in the manual of those hazards and risks specifically addressed in this document is considered to be sufficient.

S.6.5 Supplementary information

S.6.5.1 General

Addition to 6.5.1:

Enclosures provided with removable covers, as noted in S.4.12.201.10.1 e), must be marked "WARNING" and the following:

> "RISK OF ELECTRIC SHOCK – Disconnect power before removing cover."

S.6.5.2 Capacitor discharge

S.6.5.3 Special operation mode – Auto restart/bypass connection

S.6.5.4 Other hazards

Addition to 6.5.4:

A live heat sink or other part mistaken as dead metal and exposed to persons must be marked with the word "CAUTION" and the following or equivalent:

> "Risk of electric shock – Plates (or other word describing the type of part) are live – Disconnect power supply before servicing."

The marking must be located on the *live part*.

S.6.5.5 *BDM/CDM/PDS* with multiple sources of supply

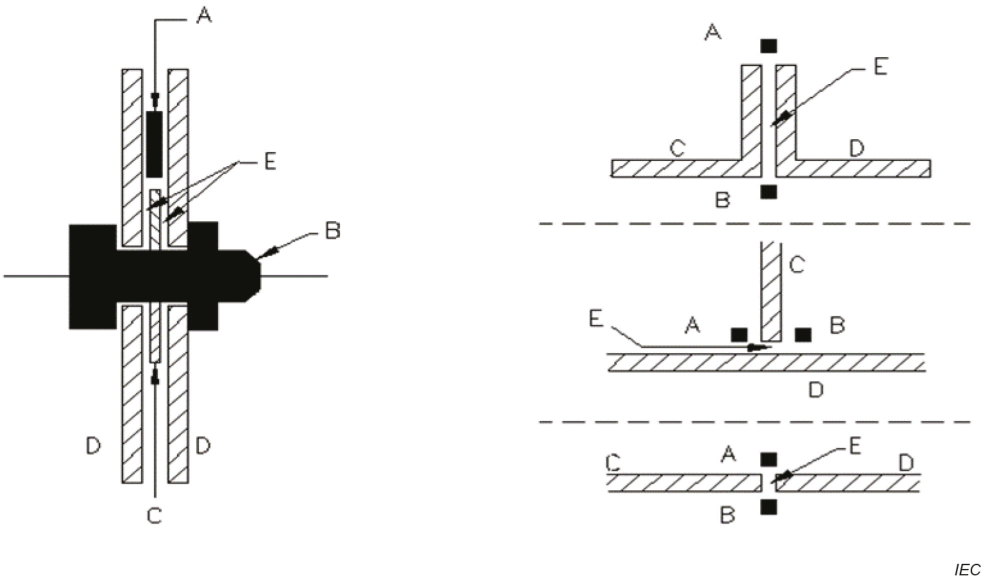
S.6.5.6 PT/CT connection

S.6.5.7 Access conditions for *high-voltage BDM/CDM/PDS* during maintenance

Additional clause:

S.200 Evaluation of clearance and *creepage distances*

A clamped joint is a joint between two pieces of *insulation* that are under pressure, as shown in Figure S.5. Adhesives, cements, and similar materials, when used to effect a seal in place of a tightly mated joint, must comply with UL 746C. When the *clearance* and *creepage distance* between parts A and B of Figure S.5 are less than those required by 4.4.7.4 and 4.4.7.5 when measured through the clamped joint, the clamped joint must comply with the test in S.5.2.3.203.



Key

Parts A, B *live part*s of opposite polarity, or a *live part* and grounded metal part with *clearance* and *creepage distances* through the crack between C and D less than required in 4.4.7.4 and 4.4.7.5

Parts C, D insulating barriers clamped tightly together, where the dielectric strength between A and B is greater than the equivalent *clearance*.

Part E the clamped joint.

Figure S.5 – Clamped joint

S.200.1 *Clearance* and *creepage distance*s

S.200.1 provides the requirements for *clearance*s and *creepage distance*s at *field wiring terminals* that do not preclude the possibility of stray strands and at points of a conductive *enclosure* where wiring methods may be installed.

Table S.23 – Minimum *clearance*s and *creepage distance*s at *field wiring terminal*s up to 600 V

Potential involved in V RMS AC or DC		**Minimum *clearance*s and *creepage distance*s, inch (mm)**							
		A			**B**		**C**		**D**
		General industrial control equipment			**Devices having limited ratings[a]**		**Other devices[b]**		**All circuits[e]**
		51 to 150	**151 to 300**	**301 to 600**	**51 to 300**	**301 to 600**	**51 to 150**	**151 to 300**	**0 to 50**
Between any un*insulated live part* and an un*insulated live part* of opposite polarity, un*insulated* grounded part other than the *enclosure*, or exposed metal part[g,h]	*Clearance*	1/8[c]	1/4	3/8	1/16[c]	3/16[c]	1/8[c]	1/4	1/16[c]
		(3,2)	(6,4)	(9,5)	(1,6)	(4,8)	(3,2)	(6,4)	(1,6)
	Creepage distance	1/4	3/8	1/2	1/8[c]	3/8	1/4	1/4	1/16
		(6,4)	(9,5)	(12,7)	(3,2)	(9,5)	(6,4)	(6,4)	(1,6)
Between any un*insulated live part* and the walls of a metal *enclosure* including fittings for conduit or armored cable[d,f]	*Clearance* and *creepage distance*	1/2	1/2	1/2	1/4	1/2	1/4	1/4	1/4
		(12,7)	(12,7)	(12,7)	(6,4)	(12,7)	(6,4)	(6,4)	(6,4)

NOTE 1 A slot, or groove, 0,013 in (0,33 mm) wide or less in the contour of insulating material is to be disregarded.

NOTE 2 An air space of 0,013 in (0,33 mm) or less between a *live part* and an insulating surface is to be disregarded for the purpose of measuring *creepage distance*s.

[a] Applicable to non-motor circuits in *BDM/CDM/PDS*:

a) Rated 720 VA break pilot duty or less; or not more than 15 A at 51 V to 150 V, 10 A at 151 V to 300 V, or 5 A at 301 V to 600 V.

b) Of the type described in a) which controls more than one load provided the total load connected to the supply at one time does not exceed 1 440 VA, or have a current rating greater than 30 A at 51 V to 150 V, 20 A at 151 V to 300 V, or 10 A at 301 V to 600 V.

[b] Applicable to *BDM/CDM/PDS* rated at 300 V or less, and 1 hp (746 W output) or less or 2 000 VA or less per pole and to a device that has a current rating per pole of 15 A or less at 51 V to 150 V, 10 A at 151 V to 300 V, or both.

[c] The *clearance*s and *creepage distance*s between *field wiring terminal*s of opposite polarity and the *clearance*s and *creepage distance*s between a *field wiring terminal* and a grounded dead metal part must be at least ¼ in (6,4 mm) when short-circuiting or grounding of such terminals results from projecting strands of wire. For circuits involving no potential greater than 50 V RMS AC or DC, *clearance*s and *creepage distance*s at field wiring terminals are able to be 1/8 in (3,2 mm) for *clearance* and ¼ in (6,4 mm) for *creepage distance*.

[d] For the purpose of this requirement, a metal piece attached to the *enclosure* is a part of the *enclosure* when deformation of the *enclosure* reduces the *clearance*s and *creepage distance*s between the metal piece and un*insulated live part*s.

[e] *Clearance*s and *creepage distance*s apply as indicated, except as specified those in pollution degree 2 per S.200.1 and the *clearance*s and *creepage distance*s between the low-potential circuit are in accordance with the requirements that are applicable to the high-potential circuit.

[f] Applicable to devices with sheet metal *enclosure*s regardless of wall thickness and cast metal *enclosure*s with a wall thickness of less than 1/8 in (3,2 mm).

[g] These *clearance*s and *creepage distance*s are also applicable between any un*insulated live part*s and the walls of a cast metal *enclosure* with a wall thickness of minimum 1/8 in (3,2 mm).

[h] These *clearance*s and *creepage distance*s are also applicable between an *insulated live part* and the wall of a metal *enclosure* to which the *component* is mounted. Deformation of the *enclosure* must not reduce *clearance*s and *creepage distance*s and result in a risk of electric shock.

Table S.24 – Minimum *clearance*s and *creepage distance*s for *field wiring terminal*s over 600 V

Potential involved, in V	**Location**	**Minimum *clearance*s and *creepage distance*s**, in (mm)			
		601 – 1 000		**1 001 – 1 500**	
Between any un*insulated live part* and an un*insulated live part* of opposite polarity, an uninsulated grounded part other than the *enclosure*, or an exposed metal part	*Clearance* through air	0,55	(14,0)	0,70	(17,8)
	Clearance through oil	0,45	(11,4)	0,60	(15,2)
	Creepage distance air	0,85	(21,6)	1,20	(30,5)
	Creepage distance oil	0,62	(15,7)	0,70	(17,8)
Between any un*insulated live part* and the walls of a metal *enclosure*, including fittings for conduit or armored cable	*Clearance* through air or oil	0,80	(20,3)	1,20	(30,5)
	Creepage distance	1,00	(25,4)	1,65	(41,9)

Table S.25 – *Clearance*s and *creepage distance*s at *field wiring terminal*s for pollution degree 2 environments

Potential involved, V		**Minimum *clearance*s and *creepage distance*s [a]**, in (mm)					
		Between field wiring terminals		**Between field wiring terminals and other uninsulated parts not always of the same polarity**			
RMS	**Peak**	***Clearance*s and *creepage distance*s**		***Creepage distance***		***Clearance***	
0 to 50	0 to 70,7	1/8	(3,2)	1/8	(3,2)	1/8	(3,2)
51 to 250	72,1 to 353,6	1/4	(6,4)	1/4	(6,4)	1/4	(6,4)
251 to 600	355,0 to 848,5	1/2	(12,7)	1/2	(12,7)	3/8	(9,5)

[a] These *clearance*s and *creepage distance*s apply to the sum of the *clearance*s and *creepage distance*s involved wherever an isolated dead metal part is interposed, without including the distance across the metal part.

For *BDM/CDM/PDS* intended for use in a pollution degree 2 environment, *clearance*s and *creepage distance*s at *field wiring terminal*s must comply with one of the following:

a) column A, B, C or D of Table S.23, including footnote c, or Table S.24; or

b) Table S.25.

The *clearance*s and *creepage distance*s at a *field wiring terminal* are to be measured with wire connected to the terminal as in service. The connected wire is to be the next larger size than is normally required for the *BDM/CDM/PDS* rating when the terminal accommodates it or when the *BDM/CDM/PDS* is not marked to restrict its use.

S.201 Normative references and component standards

US National Electrical Code, ANSI/NFPA 70

Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal, and Energy – UL 61800-5-1

Batteries, Lithium – UL 1642

Capacitors – UL 810

Component Connectors for Use in Data, Signal, Control and Power Applications – UL 1977

Controllers, Programmable – Part 2: Equipment Requirements – UL 61131-2

Cords and Cables, Flexible – UL 62

Electrical Analog Instruments – Panel Board Types – UL 1437

Electrical Equipment, Organic Coatings for Steel Enclosures for Outdoor Use – UL 1332

Electrical Wires, Cables, and Flexible Cords, Reference Standard for – UL 1581

Enclosure for Electrical Equipment, Non-Environmental Considerations – UL 50

Enclosures for Electrical Equipment, Environmental Considerations – UL 50E

Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors – UL 486E

Explosion-Proof and Dust-Ignition-Proof Electrical Equipment for Use in Hazardous (Classified) Locations – UL 1203

Fans, Electric – UL 507

Fire Test for Heat and Visible Smoke Release for Discrete Products and Their Accessories Installed in Air-handling Spaces – UL 2043

Fittings, Conduit, Tubing, and Cable – UL 514B

Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains – UL 60384-14

Fuseholders – Part 1: General Requirements – UL 4248-1

Fuseholders – Part 4: Class CC – UL 4248-4

Fuseholders – Part 5: Class G – UL 4248-5

Fuseholders – Part 6: Class H – UL 4248-6

Fuseholders – Part 8: Class J – UL 4248-8

Fuseholders – Part 9: Class K – UL 4248-9

Fuseholders – Part 11: Type C (Edison Base) and Type S Plug Fuse – UL 4248-11

Fuseholders – Part 12: Class R – UL 4248-12

Fuseholders – Part 15: Class T – UL 4248-15

Fuses, Low-Voltage – Part 12: Class R Fuses – UL 248-12

Fuses, Low-Voltage – Part 1: General Requirements – UL 248-1

Fuses, Low-Voltage – Part 11: Plug Fuses – UL 248-11

Fuses, Low-Voltage – Part 14: Supplemental Fuses – UL 248-14

Gaskets and Seals – UL 157

Ground-Fault Sensing and Relaying Equipment – UL 1053

Industrial Control Equipment – UL 508

Information Technology Equipment Safety – Part 1: General Requirements – UL 60950-1

Insulated Winding Wire, Single- and Muliti-Layer – UL 2353

Insulation Coordination Including Clearances and Creepage Distance for Electrical Equipment – UL 840

Marking and Labeling Systems – UL 969

Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures – UL 489

Rotating Electrical Machines – General Requirements – UL 1004-1

Motors, Impedance Protected – UL 1004-2

Motors, Thermally Protected – UL 1004-3

Electric Generators – UL 1004-4

Motors, Fire Pump – UL 1004-5

Motors, Servo and Stepper – UL 1004-6

Motors, Electronically Protected – UL 1004-7

Motors, Inverter Duty – UL 1004-8

Motors, Overheating Protection for – UL 2111

Optical Isolators –UL 1577

Plastic Materials for Parts in Devices and Appliances, Tests for Flammability of – UL 94

Plugs, Receptacles, and Cable Connectors of the Pin and Sleeve Type – UL 1682

Power Units, Class 2 – UL 1310

Polymeric Materials – Long Term Property Evaluations – UL 746B

Polymeric Materials – Short Term Property Evaluations – UL 746A

Polymeric Materials – Use in Electrical Equipment Evaluations – UL 746C

Power Units Other Than Class 2 – UL 1012

Printed-Wiring Boards – UL 796

Protectors, Supplementary, for Use in Electrical Equipment – UL 1077

Semiconductor Devices, Electrically Isolated – UL 1557

Service Equipment, Reference Standard for – UL 869A

Speed Controls, Solid-State Fans – UL 1917

Surge Protective Devices – UL 1449

Switches, Clock-Operated – UL 917

Switches, Enclosed and Dead-Front – UL 98

Switchgear and Controlgear, Low-Voltage – Part 1: General Rules – UL 60947-1

Switchgear and Controlgear, Low-Voltage – Part 4-1: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters – UL 60947-4-1

Switchgear and Controlgear, Low-Voltage – Part 5-2: Control Circuit Devices and Switching Elements – Proximity Switches – UL 60947-5-2

Systems of Insulating Materials – General – UL 1446

Temperature-Indicating and -Regulating Equipment – UL 8731

Terminal Blocks – UL 1059

Terminals, Electrical Quick-Connect – UL 310

Thermistor-Type Devices – UL 1434

Transformers, Low-Voltage – Part 1: General Requirements – UL 5085-1

Transformers, Low-Voltage – Part 2: General Purpose Transformers – UL 5085-2

Transformers, Low-voltage – Part 3: Class 2 and Class 3 Transformers – UL 5085-3

Transformers, Specialty – UL 506

Wire Connectors – UL 486A-486B

Wires and Cables, Machine Tool – UL 1063

Wires and Cables, Thermoplastic-Insulated – UL 83

S.202 IEC to USA standard references

In the USA, the IEC normative reference standards listed in Table S.26 do not apply.

Table S.26 – IEC normative reference standards that do not apply

IEC standard title	IEC standard number
Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state	IEC 60068-2-78:2012
Insulation co-ordination – Part 1: Definitions, principles and rules	IEC 60071-1:2019
Coding of indicating devices and actuators by colours and supplementary means	IEC 60073:2002
Graphical symbols for use on equipment – Part 2: Symbol originals	IEC 60417-2:1998, IEC 60417-2:1998/ AMD1:2000 and IEC 60417-2:1998/AMD2:2002[6]
Low-voltage switchgear and controlgear assemblies – Part 1: Type-tested and partially type-tested assemblies	IEC 60439-1:1999, IEC 60439-1:1999/ AMD1:2004
Basic and safety principles for man-machine interface, marking and identification – Identification of equipment terminals, conductor terminations and conductors	IEC 60445:2021
Basic and safety principles for man-machine interface, marking and identification – Actuating principles	IEC 60447:2004
Protection against electric shock – Common aspects for installation and equipment	IEC 61140:2016
Graphical symbols for diagrams – Part 7: Switchgear, controlgear and protective devices	IEC 60617-7:1996
Connecting devices for low-voltage circuits for household and similar purposes – Part 1: General requirements	IEC 60998-1:2002
Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test	IEC 61000-4-2:2008
Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test	IEC 61000-4-3:2020
Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical test transient/burst immunity test	IEC 61000-4-4:2012
Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test	IEC 61000-4-5:2014, IEC 61000-4-5:2014/ AMD1:2017
Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement	CISPR 11:2015/, CISPR 11:2015/AMD1:2016, CISPR 11:2015/AMD2:2019
Electromagnetic compatibility of multimedia equipment – Emission requirements	CISPR 32:2015, CISPR 32:2015/AMD1:2019

In the USA, the IEC normative references listed in Table S.27 are replaced by the indicated USA standard.

6 This publication has been withdrawn.

Table S.27 – IEC normative references replaced by USA standards

IEC standard title	IEC standard number	USA standard title	USA standard number
High-voltage test techniques	IEC 60060-1:2010	Techniques for High-Voltage Testing	ANSI/IEEE 4
Electrical insulation –Thermal evaluation and designation	IEC 60085:2007	Systems of Insulating Materials – General	UL 1446
Surge arresters – Part 1: Non-linear resistor type gapped surge arresters for AC systems	IEC 60099-1:1991, IEC 60099-1:1991/AMD1:1999	Metal-Oxide Surge Arrestors for AC Power Circuits	ANSI/IEEE C62.11
		Gapped Silicon-Carbide Surge Arrestors for AC Power Circuits	IEEE C62.1
		Surge Protective Devices	UL 1449
Method for the determination of the proof and the comparative tracking indices of solid insulating materials	IEC 60112:2020	Polymeric Materials – Short Term Property Evaluations	UL 746A
		Polymeric Materials – Use in Electrical Equipment Evaluations	UL 746C
Electrical insulating materials – Thermal endurance properties – Part 1: Ageing procedures and evaluation of test results	IEC 60216-1:2013	Polymeric Materials – Long Term Property Evaluations	UL 746B
Low-voltage fuses – Part 1: General requirements	IEC 60269-1:2006, IEC 60269-1/AMD1:2009, IEC 60269-1/AMD2:2014	Low-Voltage Fuses – Part 1: General Requirements	UL 248-1
Low-voltage fuses – Part 2: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application) – Examples of standardized systems of fuses A to K	IEC 60269-2:2013, IEC 60269-2:2013/AMD1:2016	Low Voltage Fuses – Part 4: Class CC Fuses	UL 248-4
		Low Voltage Fuses – Part 5: Class G Fuses	UL 248-5
		Low Voltage Fuses – Part 6: Class H Non-Renewable Fuses	UL 248-6
		Low Voltage Fuses – Part 7: Class H Renewable Fuses	UL 248-7
		Low Voltage Fuses – Part 8: Class J Fuses	UL 248-8
		Low Voltage Fuses – Part 9: Class K Fuses	UL 248-9
		Low Voltage Fuses – Part 10: Class L Fuses	UL 248-10
		Low Voltage Fuses – Part 11: Plug Fuses	UL 248-11
		Low Voltage Fuses – Part 12: Class R Fuses	UL 248-12
		Low Voltage Fuses – Part 13: Semiconductor Fuses	UL 248-13
		Low Voltage Fuses – Part 14: Supplemental Fuses	UL 248-14
		Low Voltage Fuses – Part 15: Class T Fuses	UL 248-15
		Low-Voltage Fuses – Part 17: Class CF Fuses	UL 248-17
Low-voltage electrical installations – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances	IEC 60364-4-44:2007, IEC 60364-4-44:2007/AMD1:2015, IEC 60364-4-44:2007/AMD2:2018	US National Electrical Code	ANSI/NFPA 70

IEC standard title	IEC standard number	USA standard title	USA standard number
Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests	IEC 60664-1:2020	Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment	UL 840
Fire hazard testing – Part 2-10: Glowing/hot-wire based test methods – Glow-wire apparatus and common test procedure	IEC 60695-2-10:2021	Polymeric Materials – Use in Electrical Equipment Evaluations	UL 746C
Fire hazard testing – Part 2-11: Glowing/hot-wire based test methods – Glow-wire flammability test method for end products (GWEPT)	IEC 60695-2-11:2021	Polymeric Materials – Use in Electrical Equipment Evaluations	UL 746C
Fire hazard testing – Part 2-12: Glowing/hot-wire based test methods – Glow-wire flammability index (GWFI) test method for materials	IEC 60695-2-12:2021	Polymeric Materials – Use in Electrical Equipment Evaluations	UL 746C
Fire hazard testing – Part 2-13: Glowing/hot-wire based test methods – Glow-wire ignition temperature (GWIT) test method for materials	IEC 60695-2-13:2021	Polymeric Materials – Use in Electrical Equipment Evaluations	UL 746C
Fire hazard testing – Part 11-5: Test flames – Needle-flame test method – Apparatus, confirmatory test arrangement and guidance	IEC 60695-11-5:2016	Polymeric Materials – Use in Electrical Equipment Evaluations	UL 746C
Fire hazard testing – Part 11-20: Test flames – 500 W flame test method	IEC 60695-11-20:2015	Test for Flammability of Plastic Materials for Parts in Devices and Appliances	UL 94
Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices	IEC 60947-5-1:2016	Low-voltage switchgear and controlgear – Part 5-1: *Control circuit* devices and switching elements – Electromechanical *control circuit* devices	UL 60947-5-1
Extra heavy-duty electrical rigid steel conduits	IEC 60981:2019	Electrical Rigid Metal Conduit – Steel	UL 6

S.203 Isolated secondary circuits and circuits supplied by battery

S.203.1 Isolated secondary circuits

S.203.1.1 General

An isolated secondary circuit is a *control circuit* that is isolated at all points from the primary branch-circuit. This isolation must be provided by means such as a transformer, optical isolator, limiting impedance, or electro-mechanical relay.

An isolated secondary circuit must comply with the following:

1) separation of circuits, S.203.1.1;
2) AC or DC voltage test of 5.2.3.4;
3) applicable requirements for one of the following types of isolated secondary circuits:
    a) class 2 circuit, see S.203.1.5 and Table S.28;
    b) limited voltage/current circuit, see S.203.1.6 and Table S.28;

c) limited energy circuit, see S.203.1.7 and Table S.28;

d) limiting impedance circuit, see S.203.1.8 and Table S.28;

e) limited voltage circuit, see S.203.1.9 and Table S.28;

f) isolated power supply circuit, see S.203.1.10 and Table S.28.

Table S.28 – Secondary circuits, differences in evaluation

Clause		Type of isolated secondary circuit								
		Class 2	**Limited voltage/ current**	**Limited energy**		**Limited impedance**			**Limited voltage**	**Isolated power supply**
S.203.1.3	Risk of electric shock present in circuit?	No	No	No	Yes	No	No	Yes	No	Yes
S.203.1.4	Risk of thermal hazard present in circuit?	No	No	Yes	Yes	No	No	No	Yes	Yes
Electrical characteristics of isolated secondary source (ISC)										
S.203.1.5 to S.203.1.10	Maximum voltage, AC	[b]	30	30	100	-	30	-	30	150
	Maximum voltage, peak	[b]	42,4	42,4	-	-	42,4	-	42,4	-
	Max. secondary current, A	[b]	8	-	-	0,005[a]	-	-	-	-
	Max. secondary power, VA	[b]	100	200	200	15 W	15 W	15 W	-	10 k
Component requirements within isolated secondary circuit (ICS)										
4.4.7	Printed wiring Boards	-	-	[c]	[c]	-	-	-	[c]	x
4.11	Internal wiring	-	-	x	x	-	-	-	x	x
	All other components	[d]	[d]	[d]	[d]	[d]	[d]	[d]	[d]	[d]
Clearance and creepage distances requirements for isolated secondary circuit (ISC)										
4.4	Within ISC	-	-	-	-	-	-	-	-	-
	Between ISC and ground	-	-	-	x	-	[e]	x	-	[e]
	Between ISC and enclosure or accessible parts	-	-	-	x	-	[e]	x	-	[e]
	Between ISC and other isolated circuits	x	x	x	x	x	x	x	x	x
Protection against direct contact										
4.4	ISC requires protection against direct contact	-	-	x	x	-	-	x	x	x
Performance requirements										

Clause		Type of isolated secondary circuit								
		Class 2	Limited voltage/ current	Limited energy		Limited impedance			Limited voltage	Isolated power supply
Isolating source (such as: transformer, power supply. limiting impedance, battery):										
S.203.1	Secondary circuit	[b]	S.203.2.2	S.203.2.3	S.203.2.3	S.203.2.4	S.203.2.4	S.203.2.4	S.203.2.5	S.203.2.6
5.2.6.3.2	Temperature	[d]	[d]	[d]	[d]	[d]	[d]	[d]	[d]	[d]
5.2.4.10	Breakdown of components	[b]	x	x	x	x	x	x	x	x
NOTE "x" indicates the requirement applies whereas " – " indicates the requirement does not apply.										
[a] See S.203.1.2 b).										
[b] See UL 1310 or UL 5085-1, and UL 5085-3, for maximum electrical characteristics and performance requirements.										
[c] Printed wiring boards must comply with UL 796, and must be rated V-2, V-1 or V-0.										
[d] No evaluation required except the effect of heat generating compounds *component*s in the isolated secondary circuit on adjacent *component*s such as printed wiring boards and wiring must be evaluated during the temperature test.										
[e] See S.203.1.10.										
[f] Tests specified in this table evaluates isolating *component*s for use with secondary circuits and does not indicate all tests applicable to the isolating *component*s.										

S.203.1.2 Separation of circuits

Factory installed isolated secondary circuits must be separated from all other circuits in accordance with the next paragraph. Insulated conductors must be separated from wiring and un*insulated live part*s connected to other circuits. Wiring and *component*s provided with *insulation* rated for the highest voltage involved are considered to be separated from each other.

Separation of insulated conductors must be accomplished by clamping, routing, or equivalent means that provides permanent separation from insulated or un*insulated live part*s of a different circuit.

A permanent barrier must be provided to separate field installed class 2 conductors of secondary circuits from all other circuits.

A permanent barrier is not required when class 1 or power conductors introduced solely to connect to *BDM/CDM/PDS* connected to a class 2 circuit and

a) provision has been made to route the class 1 or power circuit conductors to maintain a minimum 1/4 in (6,35 mm) separation from the conductors of the class 2 circuit, or
b) the class 1 or power circuit conductors operate at 150 V or less to ground and also comply with one of the following:
    1) provision has been made to enable the class 2 circuits to be installed using types CL3, CL3R, CL3P or equivalent cables, and the cable conductors extending beyond the jacket can be separated by a minimum of 1/4 in (6,35 mm) or by a nonconductive sleeve or nonconductive barrier from all other conductors; or
    2) the class 2 conductors are required to be installed as a Class 1 circuit in accordance with Section 725-21 of the US National Electrical Code, ANSI/NFPA 70.

A permanent barrier is not required for *enclosures* having provision for only one opening, when installation instructions are provided that state conductors of class 2 circuits must be separated from conductors for class 1 or power circuits by a continuous and firmly fixed type nonconductor, such as flexible tubing.

Where a permanent barrier is not provided, installation instructions must be provided to explain the wiring methods to comply with the requirements of S.203.1.2.

Field and factory installed conductors of two or more class 2 circuits are able to be routed within the same cable, *enclosure*, or raceway.

S.203.1.3 Risk of electric shock

A risk of electric shock exists within a circuit unless that circuit meets one of the following criteria:

a) the circuit is supplied by an isolating source such that the maximum open circuit voltage potential available to the circuit is not more than 30 V AC or 42,4 V peak; or
b) the circuit is supplied by an isolating source such that the current available through a 1 500 Ωhm resistor connected across any potential in the circuit (including to ground) does not exceed 5 mA.

S.203.1.4 Risk of thermal hazard

A risk of thermal hazard exists within a circuit unless that circuit meets one of the following criteria:

a) the circuit is supplied by an isolating source such that the maximum open circuit voltage potential available to the circuit is not more than 30 V AC or 42,4 V peak and the current available is limited to a value not exceeding 8 A measured after 1 min of operation; or
b) the circuit is supplied by an isolating source such that the power available to the circuit is limited to a value less than 15 W.

S.203.1.5 Class 2 circuits

A Class 2 circuit must be supplied by an isolating source that complies with the requirements in UL 1310, or the requirements in UL 5085-1 and UL 5085-3.

S.203.1.6 Limited voltage/current circuit requirements

A limited voltage/current circuit must be supplied by an isolating source such that the maximum open circuit voltage potential available to the circuit is not more than 30 V AC or 42,4 V peak and the current available is limited to a value not exceeding 8 A measured after 1 min of operation under any condition of loading to achieve the maximum current.

An isolating power supply or an isolating type transformer, tested in accordance with S.203.2.2, can be used to comply with this requirement. For a device that is intended to be supplied by an isolating source that complies with this requirement and that is intended to be supplied as an *accessory* in the field, the device must be marked as in 6.2.2.

A secondary fuse or other such secondary circuit protective device used with an isolating source to limit the available current in accordance with the first paragraph must be rated at not more than five amperes for secondary voltages less than or equal 20 V peak; or 100 VA for secondary voltages over 20 V and less than 30 V peak, where V is the peak open circuit voltage.

When a secondary fuse complying with the previous paragraph and UL 248 series of standards is used, the test specified in S.203.2.2 is not required. When this fuse and isolating source are intended to be supplied in the field, the *BDM/CDM/PDS* must be provided with installation instructions in accordance with S.6.2.1.200.2.

Protective devices other than those described in the previous paragraph and protective devices with higher ratings than described in S.203.1.6 may be used if the combination of isolating source and protective device is evaluated as in S.203.2.2. When the protective device and isolating source are intended to be supplied in the field, the *BDM/CDM/PDS* must be provided with instructions or markings as required in 6.3.2.

The secondary circuit protective device can be provided in the primary circuit. When provided in the primary circuit, there are no restrictions on the current rating of the protective device as long as it limits the available secondary current in accordance with S.203.1.6.

When a protective device is relied upon, this protective device must comply with the requirements of this document and must be provided with an adjacent replacement marking in accordance with S.6.3.9.6.1 or replacement instructions that includes the required voltage and current rating. The printed wiring board, wiring, and *clearance* and *creepage distances* prior to the point at which the voltage and current are limited must comply with the primary circuit requirements of this document.

A fixed impedance (such as a *component* or grouping of *component*s in the same circuit) or a regulating network (such as used in a switching type power supply) that is used to limit the voltage and/or the available current must be able to function under *component single-fault conditions* according to 4.2.

S.203.1.7 Limited energy circuit requirements

A limited energy circuit must be supplied by an isolating source such that the maximum volt-ampere capacity available to the circuit is 200 VA or less at a maximum open circuit voltage potential of 100 V AC. The isolating source must comply with the test described in S.203.2.3. For a device (circuit) that is intended to be supplied by an isolating source that complies with this requirement and that is intended to be supplied as a kit in the field, the device must be marked as in 6.2.2.

A primary or secondary circuit fuse or other such circuit protective device may be used to limit the maximum available volt-ampere capacity. There are no restrictions on the current rating of this protective device as long as it limits the available secondary volt-ampere limit in accordance with S.203.1.7. The protective device must comply with the requirements of this document and there must be a marking in accordance with S.6.3.9.6.1.

S.203.1.8 Limiting impedance circuit requirements

A limiting impedance circuit relied upon to reduce the risk of thermal hazard as defined in S.203.2.4 must be supplied by an impedance that complies with one the following:

a) the calculated power dissipation of the impedance, as the result of a direct short applied across the circuit limited by the impedance, does not exceed the power rating of the impedance and the power dissipation is less than 15 W; or
b) the impedance must
    1) be rated such that the calculated power dissipation of the impedance, as the result of a direct short applied across the circuit limited by the impedance, exceeds the power rating of the impedance and is still less than 15 W, and
    2) not open or short when subjected to the effects of a direct short applied across the circuit limited by the impedance as described in S.203.2.4.

The 15 W power limitation of the impedance must not be exceeded under *component single-fault conditions*.

When the circuit limited by the 15 W impedance is completely enclosed without ventilation openings, the effect of *component single-fault conditions* is not evaluated.

A limiting impedance, relied upon to reduce the risk of electric shock as defined in S.203.1.3, must comply with one of the following.

a) The limiting impedance is connected to the high potential side of or as a voltage divider across a grounded single phase supply voltage rated not more than 150 V and serves to limit the voltage within the isolated secondary circuit to be less than 30 V RMS or 42,4 V peak within the isolated secondary circuit and also with respect to ground as determined by circuit analysis.

b) The limiting impedance is connected to each of two ungrounded supply voltage lines from a 120/240 V supply or two or three ungrounded supply voltage lines from a three phase supply and serves to limit the voltage within the isolated secondary circuit to be less than 30 V RMS or 42,4 V peak within the isolated secondary circuit and also with respect to ground as determined by circuit analysis; or the circuit must be evaluated for voltage to ground present while connected to any primary voltage *system* supplying the *BDM/CDM/PDS*.

c) A secondary circuit supplied from a limiting impedance circuit is insulated from or have *clearance* and *creepage distances* to grounded metal or *accessible part*s and has no field wiring connections or does have field wiring connections if both of the following conditions are met:

   1) the *BDM/CDM/PDS* is marked with the maximum voltage to ground that can be present on the field wiring connections from secondary circuit;

   2) the circuit complies with the test in S.203.2.4 when preformed between each of the field wiring terminals, of the limiting impedance circuit, to ground.

Where a limiting impedance is relied upon to reduce the risk of electric shock as in S.203.1.3, no individual element must experience an electrical stress factor

d) greater than 0,5 times during all conditions of normal operating conditions, or

e) greater than 1,0 times after single *component* failure with respect to rated voltage, current and dissipated wattage.

The electrical stress factor is defined as ratio of applied electrical characteristic to rated electrical characteristic, such as the ratio between the applied current and the rated ampacity of a *component*.

S.203.1.9 Limited voltage circuits

A limited voltage circuit must be supplied by an isolating source that complies with the following.

a) The maximum open circuit voltage potential available to the circuit must not be more than 30 V AC or 42,4 V peak without any limitation on the available current or volt-ampere capacity.

b) All external secondary circuit interconnecting cables and all secondary circuit wiring between units must be protected against burnout and damage to the *insulation* resulting from any overload or short-circuit condition that can occur during use of the *BDM/CDM/PDS*. *Overcurrent* protective device must be provided in the secondary circuit and comply with Table S.13, or the isolated secondary circuit must comply with the secondary circuit test of S.203.2.5. *Overcurrent* protective device provided in the primary circuit of the isolating source can serve as protection for the secondary circuit when it complies with S.4.4.6.201.2 or the secondary circuit test of S.203.2.5.

c) The isolating source is intended for use in a pollution degree 2 environment.

When the protective device, which complies with Table S.13, and isolating source are intended to be supplied in the field, the device must be marked in accordance with S.6.2.1.200.2.

When the protective device and isolating source, which have been found to comply with S.203.2.5, are intended to be supplied in the field, the device must be marked in accordance with 6.2.2.

S.203.1.10 Isolated power supply circuits

An isolated power supply circuit must be supplied from the secondary of an isolating source that complies with S.203.2.6.

An isolated power supply circuit must limit transient overvoltage in the secondary to no more than 300 V peak when the input terminals of the *BDM/CDM/PDS* are subjected to a single 1,2/50 μs full-wave impulse with a crest value of 5 kV using a test generator with an effective internal impedance of 12 Ω. All power input terminals must be connected together and the impulse must be applied between this connection and ground. The *BDM/CDM/PDS* must be operative at the conclusion of the test.

For circuits rated more than 50 V, *clearance*s and *creepage distance*s must not be less than 1/8 in (3,2 mm), between *live part*s of the secondary circuit and operator-accessible metal, or grounded dead metal including the *enclosure*. For secondary circuits rated 50 volts or less, these *clearance*s and *creepage distance*s must not be less than 1/16 in (1,6 mm).

When *clearance* and *creepage distances* are less than 1/8 in (3,2 mm), the construction must withstand, without breakdown or arc-over, the application of an AC potential of twice the rated voltage plus 1 000 V (or a DC potential of 1,4 times the sum of twice the rated voltage plus 1000 V) for 60 s between the secondary and *accessible parts* or grounded noncurrent carrying metal parts. During the test, any *component* normally connected to ground is to be disconnected.

S.203.2 Secondary circuits test

S.203.2.1 General

Unless otherwise specified, the test measurements are to be made as follows.

a) The primary voltage supplied to the isolating source must be not less than the operational voltage applied to the primary when the *BDM/CDM/PDS* is supplied at the maximum rated voltage including any published positive tolerance, but not less than as specified in S.5.1.5. For an isolating source with multiple primary voltage ratings, the highest voltage rating must be used for this test. *Overcurrent* protective devices in the branch-circuit must not open as a result of this test.
b) The maximum open circuit voltage potential available to the secondary circuit under consideration is to be measured directly across the output terminals of the isolating source.
c) For an isolating source with multiple secondary circuits, only one secondary circuit is to be tested at a time. All other secondaries not under test are not required to be connected to a load.
d) The applicable voltage, current and volt-ampere capacity measurements must be made directly across the secondary output terminals of the isolating source. When a tapped transformer winding is used to supply a full-wave rectifier, the measurements are to be made from either end of the winding to the tap. When the transformer is used as part of a switching-type power supply, the measurements are to be made after the transformer secondary winding rectification means.

S.203.2.2 Limited voltage/current secondary test

With the isolating source connected as described in S.203.2.1, the open circuit voltage of each secondary must not exceed 30 V RMS or 42,4 V peak and the available current in the secondary must not exceed 8 A after 1 min.

The current available to the secondary circuit under evaluation is to be measured by connecting a variable resistive load across the source of that secondary and then continually monitor and adjust the load as necessary to maintain a secondary current that is slightly more than 8 A during the 1 min test interval. When an available current of more than 8 A is not able to be obtained under any condition of loading, up to and including a short-circuit, then the test is to be discontinued for that circuit.

S.203.2.3 Limited energy secondary test

With the isolating source connected as in S.203.2.1, the open circuit voltage of the secondary must not exceed 100 V and the calculated volt-ampere capacity must not exceed 200 VA.

The maximum volt-ampere capacity available to the secondary circuit under consideration is to be measured by connecting a variable resistive load across the source of that secondary and then measuring the voltage and current while linerarly varying the resistive load from open-circuit to short-circuit during a time of no less than 1,5 min and no more than 2,5 min. The maximum available volt-ampere capacity is calculated by multiplying the simultaneously measured values of secondary voltage and secondary current. The measured values must be obtained at least once every 0,5 s. An *overcurrent* protective device is permitted to operate prior to reducing the resistive load to simulate short-circuit conditions. If the *overcurrent* protective device operates prior to 1,5 min, then the volt-amperes must also be calculated with the secondary circuit loaded so that the current through the *overcurrent* protective device equals its *overcurrent* rating.

S.203.2.4 Limiting impedance abnormal test

The following test applies to limiting impedances relied upon to reduce the risk of thermal hazard as described in S.203.1.8. With the isolating source connected as in S.203.2.1, a limiting impedance must not emit molten metal or flames or ignite cotton loosely placed over all openings of ventilated *BDM/CDM/PDS* or totally around *open type BDM/CDM/PDS* when the secondary of the limiting impedance is short-circuited. Additional trials of this test must be performed under *component single-fault conditions*.

The following test applies to limiting impedances relied upon to reduce the risk of electric shock as described in S.203.1.8. With the limiting impedance connected as in S.203.2.1, a 1 500 Ω resistor is connected between the limiting impedance and ground. As a result of the test, the current measured through the 1 500 Ω resistor must not exceed 5 mA. Additional trials of this test must be performed under *component single-fault conditions*.

Component single-fault conditions of a circuit *component* of a limiting impedance include the following.

a) For a resistor, capacitor, or diode, or similar two-terminal solid state device, the device terminals must be open-circuited or short-circuited.
b) For a discrete solid-state device having more than two terminals, such as a transistor, SCR, triac, or similar device, any combination of terminals taken two at a time must be open- or short-circuited.
c) For an integrated circuit device, the following combinations of terminals must be tested:
    1) each pair of adjacent terminals shorted;
    2) each input terminal shorted to ground terminal;
    3) each output terminal shorted to ground terminal;
    4) each input terminal shorted to each power supply;
    5) each output terminal shorted to each power supply;
    6) each terminal open-circuited.
d) A single resistor serving as a limiting impedance is not required to be evaluated under *component single-fault conditions*.
e) A single capacitor serving as a limiting impedance that complies with the requirements in UL 60384-14 is not required to be evaluated under *component single-fault conditions*.

S.203.2.5 Limited voltage secondary test

With the isolating source connected as in S.203.2.1, an isolating source that is not provided with secondary *overcurrent* protection must be subjected to this test. As a result of the test, there must be no softening or discolouration of conductor *insulation*.

Each secondary circuit of the isolating source is operated with the secondary short-circuited until ultimate conditions occur. The opening of an integral protective device or constant temperatures are indications of ultimate conditions.

S.203.2.6 Isolated power supply test

With the isolating source connected as in S.203.2.1, the open circuit voltage of the secondary must not exceed 150 V and the short-circuit power calculated according to this test must not exceed 10 000 VA.

The maximum short-circuit power available to the secondary circuit under consideration is the product of the measured open circuit voltage and the measured maximum short-circuit current of the isolating source with any protective devices bypassed.

S.203.3 Circuits supplied by a battery

S.203.3.1 Lithium battery circuits

A lithium battery circuit must comply with the requirements in UL 1642 and one of the following:

a) the primary circuit requirements in this document;
b) the requirements in S.203.1.

S.203.3.2 Non lithium battery circuits

A non-lithium battery circuit is a primary or secondary circuit that obtains power from rechargeable or non-rechargeable, non-lithium batteries.

A non-lithium battery circuit must comply with the following:

a) the primary non-rechargeable requirements in S.203.3.3 or the secondary rechargeable/non-rechargeable requirements in S.203.3.4;
b) the primary circuit requirements in this document or the requirements in S.203.1.

S.203.3.3 Primary non-rechargeable

A primary non-rechargeable non-lithium battery circuit must involve a battery that has an output in compliance with the requirements for a class 2 or limited voltage/current secondary circuit.

S.203.3.4 Secondary rechargeable/non-rechargeable

A secondary rechargeable/non-rechargeable non-lithium battery circuit must involve a battery that has an output in compliance with the requirements for a class 2 or limited voltage/current secondary circuit.

Charging circuitry for these battery circuits must be derived from an isolating source that complies with the class 2, the limited voltage/current, or the limited energy circuit requirements in S.203.1.

S.204 Full-load motor-running currents

Table S.29 and Table S.30 provide correlation between motor horsepower ratings and full-load motor running currents for various motor voltage ratings and number of phases.

Table S.29 – Full-load motor-running currents in amperes corresponding to various AC horsepower ratings

HP	110 V to 220 V			220 V to 240 V			360 V to 380 V [a, b]		440 V to 480 V			550 V to 600 V		
	Single phase	Two phase	Three phase	Single phase	Two phase	Three phase	Single phase	Three phase	Single phase	Two phase	Three phase	Single Phase	Two phase	Three phase
1/10	3,0			1,5			1,0							
1/8	3,8			1,9			1,2							
1/6	4,4			2,2			1,4							
1/4	5,8			2,9			1,8							
1/3	7,2			3,6			2,3							
1/2	9,8	4,0	4,4,	4.9,	2,0	2,2	3,2	1,3	2,5	1,0	1,1	2,0	0,8	0,9
3/4	13,8	4,8	6,4	6,9	2,4	3,2	4,5	1,8	3,5	1,2	1,6	2,8	1,0	1,3
1	16,0	6,4	8,4	8,0,	3.2	4,2	5,1	2,3	4,0	1,6	2,1	3,2	1,3	1,7
1-1/2	20,0	9,0	12,0	10,0	4,5	6,0	6,4	3,3	5,0	2,3	3,0	4,0	1,8	2,4
2	24,0	11,8	13,6	12,0	5,9	6,8	7,7	4,3	6,0	3,0	3,4	4,8	2,4	2,7
3	34,0	16,6	19,2	17,0	8,3	9,6	10,9	6,1	8,5	4,2	4,8	6,8	3,3	3,9
5	56,0	26,4	30,4	28,0	13,2	15,2	17,9	9,7	14,0	6,6	7,6	11,2	5,3	6,1
7-1/2	80,0	38,0	44,0	40,0	19,0	22,0	27,0	14,0	21,0	9,0	11,0	16,0	8,0	9,0
10	100	48,0	56,0	50,0	24,0	28,0	33,0	18,0	26,0	12,0	14,0	20,0	10,0	11,0
15	135	72,0	84,0	68,0	36,0	42,0	44,0	27,0	34,0	18,0	21,0	27,0	14,0	17,0
20		94,0	108	88,0	47,0	54,0	56,0	34,0	44,0	23,0	27,0	35,0	19,0	22,0
25		118	136	110	59,0	68,0	70,0	44,0	55,0	29,0	34,0	44,0	24,0	27,0
30		138	160	136	69,0	80,0	87,0	51,0	68,0	35,0	40,0	54,0	28,0	32,0
40		180	208	176	90,0	104	112	66,0	88,0	45,0	52,0	70,0	36,0	41,0
50		226	260	216	113	130	139	83,0	108	56,0	65,0	86,0	45,0	52,0
60					133	154		103		67,0	77,0		53,0	62,0
75					166	192		128		83,0	96,0		66,0	77,0
100					218	248		165		109	124		87,0	99,0
125						312		208		135	156		108	125
150						360		240		156	180		125	144
200						480		320		208	240		167	192
250						602		403			302			242
300								482			361			289
350								560			414			336
400								636			477			382
500								786			590			472

[a] To obtain full-load currents for 200 V and 208 V motors, increase corresponding 220 V to 240 V ratings by 15 % and 10 %, respectively.

[b] To obtain full-load currents for 265 V and 277 V motors, decrease corresponding 220 V to 240 V ratings by 13 % and 17 %, respectively.

Table S.30 – Full-load motor-running currents in amperes corresponding to various DC horsepower ratings

HP	90 V	110 V to 120 V	180 V	220 V to 240 V	500 V	550 V to 600 V
1/10		2,0		1,0		
1/8		2,2		1,1		
1/6		2,4		1,2		
1/4[a]	4,0	3,1	2,0	1,6		
1/3	5,2	4,1	2,6	2,0		
1/2	6,8	5,4	3,4	2,7		
3/4	9,6	7,6	4,8	3,8		1,6
1	12,2	9,5	6,1	4,7		2,0
1-1/2		13,2	8,3	6,6		2,7
2		17,0	10,8	8,5		3,6
3		25,0	16	12,2		5,2
5		40,0	27,0	20,0		8,3
7-1/2		58,0		29,0		12,2
10		76,0		38,0		16,0
15		110,0		55,0	27,0	24,0
20		148,0		72,0	34,0	31,0
25		184,0		89,0	43,0	38,0
30		220,0		106,0	51,0	46,0
40		292,0		140,0	67,0	61,0
50		360,0		173,0	83,0	75,0
60				206,0	99,0	90,0
75				255,0	123,0	111,0
100				341,0	164,0	148,0
125				425,0	205,0	185,0
150				506,0	246,0	222,0
200				675,0	330,0	294,0

[a] The full-load current for a 1/4 hp, 32 V DC motor is 8,6 A.

Annex T
(informative)

In-some-country requirements – Canada voltages up to 34,5 kV

T.0 General

The following clauses are applicable to BDM/CDM/*PDS* intended for installation in Canada. These requirements either add to, modify, replace or delete the requirements found in the main part of this document. Unless stated otherwise, these requirements are in addition to the original requirements of this document. The current and complete list of Canadian national differences is published in CSA C22.2 No.274-17.

The clauses in Annex T follow the numbering of those in the main part of the document. The main structure of this document is mirrored in this Annex T as headlines inserted as active links to give an easy possibility to jump to the aplipicable IEC text. Any additional numbered items are numbered starting from 200.

NOTE CSA C22.2 No.274-17 is intended to be replaced by CSA C22.2 No.61800-5-1.

T.1 Scope

Replacement of Clause 1:

1) This document applies to
   a) adjustable speed drive (*BDM*/*CDM)* connected to *mains supply* voltages up to 34,5 kV, AC 50 Hz or 60 Hz or DC,
   b) *integrated PDS* (hereafter called as *PDS*) where the motor and *BDM/CDM/PDS* are mechanically integrated into a single unit,
   c) *BDM/CDM/PDS* for use in ordinary locations in accordance with the Canadian Electrical Code, Part I, and
   d) *BDM*/*CDM*/*PDS* intended for use in an *ambient temperature* range of 0 to 40 °C.
2) This document does not apply to
   a) solid state single phase, motor speed controls rated 300V/20A and less that are covered by CSA C22.2 No. 156,
   b) motors as covered by CSA C22.2 No. 100, and
   c) cord-connected *BDM/CDM/PDS*.

T.2 Normative references

Replacement of Clause 2:

C22.1:21, *Canadian Electrical Code (CEC) – Part I*

CSA C22.2 No. 0:20, *General requirements – Canadian Electrical Code – Part II*

CSA C22.2 No. 0.2:16 (R2020), *Insulation coordination*

C22.2 No. 0.4-17, *Bonding of Electrical Equipment*

CSA C22.2 No. 0.5:16 (R2020), *Threaded conduit entries*

CSA C22.2 No. 4:16 (R2020), *Enclosed and dead-front switches*

CSA C22.2 No. 5:16 (R2021), *Molded-case circuit breakers, molded-case switches and circuit-breaker enclosures*

C22.2 No. 14-18, *Industrial control equipment*

CAN/CSA-C22.2 No. 0.17-00 (R2018), *Evaluation of Properties of Polymeric Materials*

CAN/CSA-C22.2 No. 65-18, *Wire connectors*

C22.2 No. 66.3-06 (R2020), *Low voltage transformers – Part 3: Class 2 and Class 3 transformers*

CSA C22.2 No. 77:14 (R2019), *Motors with inherent overheating protection*

CSA C22.2 No. 94.1:15 (R2020), *Enclosures for electrical equipment, non-environmental considerations*

CSA C22.2 No. 94.2:20, *Enclosures for electrical equipment, environmental considerations*

CSA C22.2 No. 100:14 (R2019), *Motors and generators*

CSA C22.2 No. 248.16:00 (R2019), *Low-voltage fuses – Part 16: Test limiters*

C22.2 No. 253:20, *Medium-voltage ac contactors, controllers, and control centres*

C22.2 No. 269.5-17, *Surge protective devices – Type 5 – Components*

CSA C22.2 No. 4248.9:07 (R2021), *Fuseholders – Part 9: Class K*

CSA C22.2 No. 60529:16 (R2021), *Degrees of protection provided by enclosures (IP code)*

CSA C235:19, *Preferred voltage levels for ac systems, 0 to 50 000 V*

ASTM (American Society for Testing and Materials)

D1868-07, *Standard Test Method for Detection and Measurement of Partial Discharge (Corona) Pulses in Evaluation of Insulation Systems*

D3638-12, *Standard Test Method for Comparative Tracking Index of Electrical Insulating Materials*

D3874-12, *Standard Test Method for Ignition of Materials by Hot Wire Sources*

IEEE (Institute of Electrical and Electronics Engineers)

IEEE 4-1995, *IEEE Standard Techniques for High-Voltage Testing*

IEEE C37.09-1999, *IEEE Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis*

T.3 Terms and definitions

T.3.7
basic insulation
Replacement of 3.7 with CSA C22.2 No. 0 basic insulation.

T.3.11
clearance
Replacement of 3.11 with CSA C22.2 No. 0 clearance distance.

T.3.12
control circuit
Replacement of 3.12 with CSA C22.1 CE Code Part I control circuit.

T.3.18
creepage distance
Replacement of 3.18 with CSA C22.2 No. 0 Creepage distance.

T.3.32
extra-low voltage
Replacement of 3.32 with CSA C22.1 CE Code Part I extra-low voltage.

T.3.40
high-voltage BDM/CDM/PDS
Replacement of 3.40 with CSA C22.1 CE Code part I high voltage.

T.3.45
live part
Replacement of 3.45 with CSA C22.1 CE Code part I live part.

T.3.46
low-voltage
Replacement of 3.46 with CSA C22.1 CE Code part I low voltage.

T.3.70
reinforced insulation
Replacement of 3.70 with CSA C22.2 No.0 reinforced insulation.

T.3.84
supplementary insulation
Replacement of 3.84 with CSA C22.2 No.0 Supplementary insulation.

Additional terms and definitions:

T.3.200
microenvironment
conditions immediately surrounding a *clearance* or *creepage distance*

Note 1 to entry: Microenvironment conditions, rather than the general environment, determine the effect on *insulation*. A microenvironment can be more or less severe than the general environment, and includes all factors affecting *insulation*, such as climate, electromagnetism, and pollution.

T.3.201
timed current limiting control
current limiting control that incorporates a timing device to either shut off or reduce the output current

T.3.202
tripping current
output current of the *BDM*/*CDM*/*PDS* at which the motor overload function is initiated

T.4 Protection against hazards

T.4.1 General

Addition to 4.1:

1) General requirements applicable to this document are given in the latest edition of CSA C22.2 No.0.
2) There are no requirements for *components* of secondary circuits that are
   a) supplied by
      i) a transformer that complies with the requirements for a transformer for a Class 2 circuit, as specified in CSA C22.2 No. 66.3,
      ii) an isolated power supply that has an *overcurrent* protective device rated 5 A max. for open-circuit voltages of 20 V RMS or less and 100/V for voltages over 20 up to 30 V RMS, or
      iii) a combination of transformer and impedance that limits the current to 5 A, under any conditions of non-capacitive loading, as measured 1 min after energization, for open-circuit voltages of 20 V RMS or less and 100/V for voltages over 20 up to 30 V RMS; and
   b) not safety circuits.
3) A contactor in a power circuit used in an *BDM/CDM/PDS* must be suitable for controlling the connected load, including making, carrying, and breaking the load current. A contactor with lower ratings may be used when it is interlocked or sequenced in such a way that, under normal operating conditions, the contactor operates within its own ratings.

T.4.2 *Single-fault conditions* and *abnormal operating condition*

T.4.3 Short-circuit and overload protection

T.4.3.1 General

Addition to 4.3.1:

T.4.13.6.200, 4), 5) and 7), applies.

Modification to 4.3.1:

IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017, 411.3.2 and 415.2, are not applicable.

T.4.3.2 Input short-circuit rating and available *output short-circuit current*

T.4.3.3 Short-circuit coordination (upstream protection)

T.4.3.4 Protection by several devices

T.4.3.5 Motor overload and overtemperature protection

T.4.3.5.1 Means of protection

Replacement of 4.3.5.1 with T.4.13.6.200, 8) 21)g).

T.4.4 Protection against electric shock

T.4.4.1 General

T.4.4.2 *Decisive voltage class (DVC)*

T.4.4.3 Provision for *basic protection*

T.4.4.3.3 Protection by means of *enclosures* or barriers

Replacement of 4.4.3.3:

*Live part*s must be arranged in *enclosure*s or located behind barriers, which must be according to requirements in T.4.12.

T.4.4.4 Provision for *fault protection*

T.4.4.4.1 General

T.4.4.4.2 *Protective equipotential bonding*

T.4.4.4.2.1 General

Addition to 4.4.4.2.1:

BDM/*CDM*/*PDS* must comply with the requirements of CSA C22.2 No. 0.4, except that the test current for the impedance test must be based on the ampere rating of the device.

Modification to 4.4.4.2.1:

4.4.4.2.1 b) is not applicable.

T.4.4.4.2.2 Rating of *protective equipotential bonding*

4.4.4.2.2 b) is not applicable.

T.4.4.4.3 *PE conductor*

T.4.4.4.3.1 General

Modification to 4.4.4.3.1:

A *PE conductor* size must be in according to T.4.4.4.3.2 4) and color must be in according to CSA C22.2 No. 0.4.

Replacement of Table 4 *with Table T.2.*

T.4.4.4.3.2 Means of connection for the *PE conductor*

Modification to 4.4.4.3.2:

1) Provision for grounding and bonding for *BDM/CDM/PDS* must be provided and be terminated by one of the following ways in T.4.4.4.3.2 2) or terminated by approved grounding and bonding kits.
2) Bonding terminations must be provided for, at a minimum, the following number of bonding conductors:
   a) power device *enclosure*s: one bonding conductor for each incoming and outgoing power circuit, based on one circuit for three poles or less and one circuit for each additional three poles or less, plus one bonding conductor for the *control circuit* where applicable;

b) cast-metal *enclosure*s for power devices that have provision for only one conduit entry: one bonding conductor;

c) auxiliary device *enclosure*s: one bonding conductor.

3) The maximum number of conductors on each termination must be determined in accordance with Table T.1.

Table T.1 – Size and number of bonding conductors per termination

Type of termination	**Maximum conductor size** AWG	**Maximum number of conductors**
Binding head screw	No. 10	1
Screw with retaining means	No. 10	2
Wire connectors as per CAN/CSA-C22.2 No. 65 (a) single conductor (b) multiple conductor (c) saddle clamp type	As certified As certified As certified	1 [a] As certified [a] 2
[a] Where a connector is certified for a range of conductor sizes, more than one conductor may be terminated in one connector, provided that the conductors are twisted together before inserting in the connector and the *BDM/CDM/PDS* is so marked (see T.6.2.1.200 3)). Conductors larger than No. 6 AWG must not be twisted together.		

4) For determining the suitability of the bonding termination, the bonding conductor size must be

a) No. 14 AWG copper or No. 12 AWG aluminum for *control circuit*s and auxiliary devices, or

b) selected from Table T.2 for power circuits and devices.

NOTE Examples of auxiliary devices include limit switches, push-button switches, and relays.

Table T.2 – Size of bonding conductor

Maximum rating of circuit A	**Size of bonding conductor** AWG		**Size of metallic conduit or pipe** AWG	**Size of electrical metallic tubing** AWG
	Copper wire	**Aluminum wire**		
20 30 40 60	14 12 10 10	12 10 8 8	1/2 1/2 1/2 3/4	1/2 1/2 1 1
100 200 300 400	8 6 4 3	6 4 2 1	1 1-1/4 1-1/4 2-1/2	1-1/4 1-1/2 1-1/2 2-1/2
500 600 800	2 1 0	0 00 000	2-1/2 3 4	2-1/2 4 4
1 000 1 200 1 600 2 000	00 000 0000 250 kcmil	0000 250 kcmil 350 kcmil 400 kcmil	4 6 — —	4 — — —
2 500 3 000 4 000 5 000 6 000	350 kcmil 400 kcmil 500 kcmil 700 kcmil 800 kcmil	500 kcmil 600 kcmil 800 kcmil 1 000 kcmil 1 250 kcmil	— — — — —	— — — — —

5) For polymeric *enclosure*s

   a) An *enclosure* employing insulating material, either wholly or in part, must have a suitable bonding means provided to ensure continuity of bonding between all conduit openings and any external metal parts that can become energized. This suitable bonding means must be either completely assembled to the product or provided as separate parts for field installation. An *enclosure* designed for field assembly of the bonding means must be provided with complete instructions to ensure proper installation. The instructions must include identification of the suitable parts and their method of installation (see T.6.2.1.200 4)).

   b) A separate bonding conductor must be copper, a copper alloy, or other material suitable for use as an electrical conductor. Ferrous metal parts in the grounding path must be suitably protected against corrosion by enameling, galvanizing, plating, or other equivalent means. A separate bonding conductor must

      i) be protected from mechanical damage or be located within the confines of the outer *enclosure* or frame, and

      ii) not be secured by a removable fastener used for any purpose other than bonding. The ends of the bonding conductor must be in metal-to-metal contact with the parts to be bonded.

   c) The size of a separate *component* bonding conductor must be not less than the size specified in Table T.2 or the size of the conductor supplying the *component*, whichever is smaller.

   d) Means must be provided to facilitate bonding to ground the secondaries of *control circuit* transformers.

   e) Instrument transformer secondary circuits must be grounded. Such grounding must be made, without fuses in the grounding circuit, directly to the ground bus, or stud if a ground bus is not provided, and the grounding conductors must not be used for grounding non-current-carrying metal parts.

      There are some relaying *system*s where grounding at the equipment is not feasible. In such cases, only one suitable point in the transformer secondary network need be grounded.

T.4.4.4.3.3 *Touch current* in case of failure of *PE conductor*

4.4.4.4.3 is not applicable.

T.4.4.5 Provisions for *enhanced protection*

T.4.4.6 Protective measures

T.4.4.7 *Insulation*

T.4.4.7.1 Influencing factors

T.4.4.7.1.1 General

Modification to 4.4.7.1.1:

The motor *insulation system* must comply with CSA C22.2 No. 100 or C22.2 No.77.

Addition to 4.4.7.1.1:

Clearance and *creepage distances* at fuses and fuseholders, measured with the fuses in place, must be based on the use of fuses having maximum standard dimensions.

Table T.3 – Minimum *clearance* and *creepage distances* on *field wiring* terminals

Group		Nominal voltage involved V	Minimum *clearances*, air mm			
			Between bare *live parts* of opposite polarity and between bare *live parts* and grounded metal parts other than the *enclosure*		Between bare *live parts* and the walls of metal *enclosures*, including fittings for conduit or armoured cable*	
			Clearance	***Creepage distance***	***Clearance***	***Creepage distance***
A	General industrial control apparatus	51 to 150 151 to 300 301 to 600 601 to 1 000 1 001 to 1 500	3,0 6,3 9,4 14,0 17,8	6,3 9,4 12,7 21,6 30,5	12,7 12,7 12,7 20,3 30,5	12,7 12,7 12,7 25,4 41,9
		601 to 1 000 1001 to 1 500 2 500 7 200 15 000 34 500	11,4 15,2 25,4 50,8 101,6 150	15,7 17,8 50,8 88,9 124,3 200	20,3 30,5 50,8 76,2 101,6 125	25,4 41,9 76,2 102 127 145
B	Devices having limited ratings	51 to 150 151 to 300 301 to 600	1,5 [a] 1,5 [a] 4,6 [a]	1,5 [a] 3,0 [a] 9,4	6,3 6,3 12,7	6,3 6,3 12,7
C	Other small devices	51 to 150 151 to 300	3,0 [a] 6,3	6,3 6,3	6,3 6,3	6,3 6,3

[a] The *clearance* and *creepage distances* between wiring terminals of opposite polarity and the *clearance* and *creepage distances* between a wiring terminal and a grounded non-current-carrying metal part must be not less than 6,3 mm if short-circuiting or grounding of such terminals can result from projecting strands of wire.

Additional subclause:

T.4.4.7.1.200 *Clearance* and *creepage distances*

1) *Clearance* and *creepage distances* at a *field wiring terminals* must be measured with wire of the appropriate size for the rating connected to the terminal as in actual service, and must be in according with Table T.3.

   In a circuit involving voltages of 50 V or less, *clearance* and *creepage distances* at *field wiring terminals* may be 3,2 mm through air and 6,3 mm over surface.

2) In an *open type BDM/CDM*, the *clearance* and *creepage distances* between *live parts* and metal parts that can be grounded (e.g., the heads of mounting screws that pass through an insulating panel) must be judged as if the parts were grounded parts within an *enclosure*. The *clearance* and *creepage distances* between bare *live parts* and the surface on which the device can be mounted must be judged as if the mounting surface were part of an *enclosure*.

3) *Clearance* and *creepage distances* are not specified for a circuit with a voltage of not more than 30 V and supplied by a primary battery, a standard class 2 transformer, or a suitable combination of transformer and fixed impedance with output characteristics that comply with the requirements for a class 2 transformer. In the field wiring area, provisions for wiring for these circuitries must be separated from other circuits in accordance with CSA C22.1 CEC rule 16-212, 16-214.

4) If contact arms, blades, etc. in a *PDS* remain connected to the motor load terminals when in the OFF position, the *clearance* and *creepage distances* from such parts in the OFF position to the enclosure or to exposed non-current-carrying metal parts that are isolated (insulated), in addition to but not in place of *clearance* and *creepage distances* required otherwise, must be not less than 3,2 mm. In a series circuit, the *clearance* and *creepage distances* between resistor terminals, transformer taps, etc. must be based on the normal operating voltage existing between such parts.

5) Gaskets or seals, if used to obtain the required *clearance* and *creepage distances*, must be suitable for the application. They must be so mounted that they are not easily damaged and must be securely held in position.

6) When measuring a *clearance* and *creepage distances* between a bare live part and a bushing installed in the knockout, it must be assumed that a bushing with the dimensions specified in Table T.4 is in place, in conjunction with a single locknut installed on the outside of the enclosure.

7) A bare *live part*, including a terminal, must be secured to its supporting surface by a method other than friction between surfaces so that it will be prevented from turning or shifting in position if such motion can result in reduction of *clearance* and *creepage distances* to less than those required by 4.4.1 to 4.4.7. The security of a contact assembly must ensure the continued alignment of contacts.

8) A pressure terminal connector need not be prevented from turning, provided that no *clearance* and *creepage distances* less than those required result when the terminals are turned 30 ° toward each other, toward other uninsulated parts of opposite polarity, or toward grounded metal parts.

9) A live screw head or nut on the underside of an insulating base must be prevented from loosening and must be adequately insulated or spaced from the mounting surface. This must be accomplished by countersinking such parts not less than 3,2 mm in the clear, and then covering them with a waterproof, insulating sealing compound that does not melt at a temperature 15 °C higher than its normal operating temperature in the device, and not less than 65 °C in any case; or securing such parts and insulating them from the mounting surface by means of a barrier, or the equivalent, or by means of through-air or over-surface *clearance* and *creepage distances* specified in Table T.3.

Table T.4 – Dimensions of bushings

Trade size of conduit in	**Bushing dimensions** mm	
	Overall diameter	**Height**
1/2	25,4	9,5
3/4	31,4	10,7
1	40,5	13,1
1-1/4	49,2	14,3
1-1/2	56,0	15,1
2	68,7	15,8
2-1/2	81,8	19,1
3	98,4	20,6
3-1/2	112,7	23,8
4	126,2	25,4
4-1/2	140,9	27,0
5	158,0	30,2
6	183,4	31,8

T.4.4.7.1.2 *Working voltage*

T.4.4.7.1.3 Pollution degree

Modification to 4.4.7.1.3:

1) When *BDM/CDM/PDS* are designed for other than pollution degree 3, the pollution degree must be marked on the *BDM/CDM/PDS* (see T.6.3.3).
2) The pollution degree category may be achieved as follows.
   a) Degree 1 can be achieved by the encapsulation or hermetic sealing of the microenvironment. For printed circuit boards, coatings may be used that comply with the performance criteria of 5.2.3.2.
   b) Degree 2 can be achieved by reducing the possibility of condensation or high humidity at a creepage distance, by providing ventilation or the continuously applying heat, through the use of heaters or continuous energizing of the equipment when it is in use. Continuous energizing is considered to exist when the equipment is operated without interruption every day, for 24 h per day, or when the equipment is operated with interruptions of a duration which do not permit cooling to the point of allowing condensation to occur.
   c) Degree 3 can be achieved by the use of enclosures that act to exclude or reduce environmental influences (e.g., moisture in the form of water droplets).
   d) Table 20 is not applicable.

T.4.4.7.1.4 Overvoltage category (OVC)

Addition to 4.4.7.1.4:

When *BDM/CDM/PDS* are design for other than overvoltage category III, the overvoltage category must be marked on the *BDM/CDM/PDS* (see T.6.3.3).

T.4.4.7.1.7.2 For *non-mains supply*

Modification to 4.4.7.1.7.2:

IEC 62477-1:2022 is not applicable.

T.4.4.7.2 *Insulation* to the *surroundings*

T.4.4.7.3 *Functional insulation*

T.4.4.7.4 *Clearance*

T.4.4.7.5 *Creepage distances*

T.4.4.7.6 Coating or potting

T.4.4.7.7 *Clearance* and *creepage distances* for *functional insulation* on PWB and *components* assembled on PWB

Addition to 4.4.7.7:

Decreased *clearance* and *creepage distances* on PWB are permitted when the *clearance* and *creepage distances* are not used for a safety circuit.

T.4.4.7.8 *Solid insulation*

T.4.4.7.8.1 General

T.4.4.7.8.2 Material requirements

Addition to 4.4.7.8.2:

Insulating material with a thickness less than that specified in 4.4.7.8.2 and 4.4.7.8.3 may be used in *BDM/CDM/PDS* rated 600 V and less if the insulating material is

a) subjected to a 60 s dielectric voltage-withstand test using the *impulse withstand voltage* from Table T.5 or AC the RMS test voltage from Table T.6 as applicable, corresponding to the required *clearance*, or
b) selected from Table T.7, in which case the generic material is considered suitable for the application without the dielectric voltage-withstand test.

Table 13 – Generic materials for *insulation* material

Addition to Table 13*:*

In other cases, the insulating material must comply with the glow-wire test described in CSA C22.2 No. 0.17 at a test temperature of 850 °C. The alternative hot wire ignition test of CSA C22.2 No. 0.17 may be used.

IEC 60695-2-11:2021 and IEC 60695-10-2:2014 are not applicable.

T.4.4.7.8.3 Thin sheet or tape material

T.4.4.7.8.4 Printed wiring boards (PWBs)

T.4.4.7.8.4.3 Use of coating materials

4.4.7.8.4.3 is not applicable.

T.4.4.7.8.5 Potting materials

Addition to 4.4.7.8.5:

Moulded thermoplastic bases and supports must be subjected to the mould stress relief distortion test in 5.2.2.4.5 as applicable.

Table T.5 – Test voltages for verifying *clearance*s

End-product standard specified minimum through-air distance mm	Test voltages kV				
	impulse withstand voltage AC peak, or DC				
	Altitude[a] m (air pressure, kPa)[b]				
	0 (101,3)	**200 (98,8)**	**500 (95,0)**	**1 000 (90,0)**	**2 000 (80,0)**
0,4	1,7	1,7	1,7	1,6	1,5
0,8	2,2	2,1	2,1	2	1,9
1,2	2,75	2,7	2,55	2,5	2,3
1,6	3,3	3,3	3,2	3	2,7
2,4	4,4	4,3	4,1	3,9	3,5
3,2	5,3	5,2	5	4,8	4,3
4,8	6,9	6,8	6,6	6,2	5,6
6,4	8,3	8,2	7,9	7,5	6,8
9,5	10,9	10,7	10,3	9,8	8,8
12,7	14	13,7	13,2	12,5	11,2
25,4	25,5	24,6	24	22,7	20,2

[a] Next lower specified altitude must be used for intermediate altitudes.

[b] Values of air pressure in kilopascals are provided to permit testing at pressures simulating elevations differing from the elevation of the test facility.

Table T.6 – Test voltages for verifying *clearance*s using AC RMS

End-product standard specified minimum through-air distance mm	Test voltages kV				
	AC RMS				
	Altitude[a] m (air pressure, kPa)[b]				
	0 (101,3)	**200 (98,8)**	**500 (95,)**	**1 000 (90,0)**	**2 000 (80,0)**
0,4	1,2	1,2	1,2	1,2	1,1
0,8	1,5	1,5	1,5	1,4	1,3
1,2	1,95	1,9	1,9	1,75	1,6
1,6	2,4	2,3	2,3	2,1	1,9
2,4	3,1	3	2,9	2,8	2,5
3,2	3,7	3,7	3,6	3,4	3
4,8	4,9	4,8	4,7	4,4	4
6,4	5,9	5,9	5,6	5,3	4,8
9,5	7,7	7,7	7,3	7	6,3
12,7	9,9	9,7	9,3	8,9	7,9
25,4	18,2	17,6	17,1	16,2	14,4

[a] Next lower specified altitude must be used for intermediate altitudes.

[b] Values of air pressure in kilopascals are provided to permit testing at pressures simulating elevations differing from the elevation of the test facility.

Table T.7 – Generic material acceptable as a barrier

Material	Minimum barrier thickness mm	Minimum barrier thickness when used in addition to not less than one-half of the required through-air distance mm	*Insulation* class °C
Electrical grade paper	0,66	0,33	105
Impregnated rag paper	0,51	0,253	105
Acetate cloth	1,32	0,66	105
Acetate film	0,44	0,22	105
Glassine	0,44	0,22	105
Varnished cambric	0,4	0,198	105
Polyamide	0,33	0,165	130
Polyethylene terephthalate film	0,33	0,165	130
Polyester film	0,33	0,165	130
Polybutylene terephthalate	0,33	0,165	130
Silicon-impregnated glass cloth	0,66	0,33	180
Aramid paper	0,33	0,163	220
PTFE sheet	0,22	0,11	250
Polyimide	0,11	0,055	250

T.4.4.8 Compatibility with residual current-operated protective devices (RCD)

T.4.4.9 Capacitor discharge

Replacement of 4.4.9:

Capacitors within an *BDM/CDM/PDS* must be discharged to a voltage less than 50 V, or to a residual charge less than 50 µC, within 1 min after the removal of power from the *BDM/CDM/PDS* for *BDM/CDM/PDS* rated 750 V or less, and within 5 min for *BDM/CDM/PDS* rated over 750 V.

If this requirement cannot be achieved for functional or other reasons, the information and marking requirements of 6.5.2 must apply. See 5.2.3.8 for test.

This requirement also applies to capacitors used for power factor correction, filtering, etc.

T.4.4.10 Access conditions for high-voltage sections of *BDM/CDM/PDS* (*interlock*)

Addition subclause to 4.4.10:

T.4.4.10.200 Access conditions for high-voltage sections of *BDM/CDM/PDS* (*interlock*)

1) *High-voltage BDM/CDM/PDS* must be provided with mechanical *door interlock*s. *Interlock*s may be activated by mechanical or electrical means.
2) *Door interlock*s must be tested per 5.2.2.8 and meet the following requirements.
   a) *Interlock*s must prevent the opening of a *door* to a high-voltage compartment when the isolating means is closed.
   b) *Interlock*s must prevent the isolating means from being closed when the *door* of any high-voltage compartment of the controller is open.

c) Where a *high-voltage BDM/CDM/PDS* is being back fed by other power source(s) (e.g., a bypass contactor or an isolating contactor), *interlock*s must be provided to prevent opening of a *door* to a high-voltage compartment when the isolating means of the back-fed power source is closed, and to prevent closing of the isolating means of the back-fed power source when a *door* to a high-voltage compartment is open.

NOTE 1 Key interlocking schemes are considered to meet this requirement.

3) Other than as specified in T.4.4.10.200 4), *high-voltage BDM/CDM/PDS* must comply with the *enclosure*, isolating and interlocking means, and barrier requirements of CSA C22.2 No. 253.

4) *High-voltage BDM/CDM/PDS* that is not provided with the isolating means must comply with the following.

   a) The *high-voltage BDM/CDM/PDS* must be marked to indicate that external isolating means is required.

   b) The *high-voltage BDM/CDM/PDS* must be provided with instructions indicating the specific external isolating means that must be provided.

   c) The *high-voltage BDM/CDM/PDS* must be provided with means for interlocking with the specified external isolating means.

   NOTE 2 This requires that a portion of the *interlock system* be installed on the *BDM/CDM/PDS*, and the remaining portion (that is installed on the external isolating means) be provided in the form of a kit, which is shipped with the *BDM/CDM/PDS*. This kit has to include all the necessary parts of the *interlock*, all hardware required to install the *interlock*, and specific instructions detailing the installation of the *interlock* on the isolating means.

   d) When the *interlock* is properly installed on the external isolating means, the resulting assembly must comply with the interlocking and isolation requirements of CSA C22.2 No. 253.

5) If *high-voltage BDM/CDM/PDS* is provided with a drawout element as the isolating means, it must comply with the applicable requirements of CSA C22.2 No. 253.

6) Any arrangement of two or more contactors must be mechanically and electrically interlocked to prevent a phase-to-phase fault if they were in the closed position at the same time. Examples can include

   a) bypass contactors, and

   b) dynamic braking contactors and phase contactors.

7) Where a means for circumventing the *door interlock* described in T.4.4.10.200 2) is provided for *visual inspection* in 5.2.1 or maintenance purposes, a degree of difficulty to bypass the *interlock* must be ensured. The degree of difficulty must involve a minimum of two separate and distinct operations. Turning a knob, moving a lever, removing a single bolt, etc., must not be considered to provide the required degree of difficulty. If an *interlock* is provided between the *door* and the switching mechanism of a *high-voltage BDM/CDM/PDS*, there may be provision for circumventing the *interlock* for *visual inspection* in 5.2.1 purposes while the switch is in the ON position. A single operation defeat mechanism may be used.

8) IEC 62271-102:2018 and IEC 61230:2008 are not applicable.

T.4.5 Protection against electrical energy hazards

T.4.5.3 Limited power sources

Addition to 4.5.3*:*

The using of positive temperature coefficient device in compliance with IEC 60730-1:2013, IEC 60730-1:2013/AMD1:2015 and IEC 60730-1:2013/AMD2:2020 in 4.5.3 b) is not applicable.

T.4.6 Protection against fire and thermal hazards

T.4.6.1 General

T.4.6.2 Circuits and *components* representing a fire hazard

T.4.6.3 Selection of *components* to mitigate the risk of a fire hazard

Modification to 4.6.3:

IEC 60695-11-10:2013 is not applicable, replaced with CSA C22.2 No.0.17.

T.4.6.4 Fire protection provided by *enclosures*

T.4.6.4.1 General

T.4.6.4.2 General *enclosure* requirement

Modification to 4.6.4.2:

1) Polymeric *enclosure* must comply with 5.2.2.4.3, 5.2.5.5 and T.5.2.2.4.200.

   Material of an *enclosure* used as electrical *insulation* must withstand the dielectric strength test specified in T.5.2.3.4.2 between current-carrying parts and the exposed non-current-carrying metal parts and/or conductive foil on the outside of the *enclosure.*

2) A non-metallic plug or other *closure* assembled to a sheet metal box as part of the *enclosure*, in accordance with CAN/CSA-C22.2 No. 0.17, must be considered acceptable under any one of the following conditions:

   a) the closure is a maximum of 645 mm^2 in area and the closure material is classified as V-0, V-1, or V-2;

   b) the closure is a maximum of 645 mm^2 in area, the closure material is classified as HB, and the closure complies with the flame test requirements in 5.2.5.5 and T.5.2.5.5;

   c) the closure is a maximum of 645 mm^2 in area, the closure material is classified as V-0, V-1, V-2, or HB, and the closure is used as a pilot light lens; or

   d) the closure is more than 645 mm^2 in area, the closure material is classified as V-0, V-1, V-2, or HB, and the closure complies with the flammability and impact test requirements in 5.2.5.5, T.5.2.5.5 and T.5.2.2.4.200.

T.4.6.4.3 *Open type BDM/CDM* intended to be installed in additional *enclosure* or *restricted-access area*

T.4.6.4.4 *BDM/CDM* designed to mitigate fire hazard by means of the *enclosure*

Replacement of 4.6.4.4:

The *BDM/CDM* is built into *fire enclosure* meeting the general *enclosure* requirements in T.4.6.4.2 and T.4.12.

T.4.6.5 Temperature limits

T.4.7 Protection against mechanical hazards

T.4.7.1 General

T.4.7.2 Critical torsional speed

T.4.7.3 Transient torque analysis

T.4.7.4 Specific requirements for liquid cooled *BDM/CDM/PDS*

T.4.7.4.1 General

T.4.7.4.2 Coolant

T.4.7.4.3 Design requirements

T.4.7.4.3.1 General

T.4.7.4.3.2 Corrosion resistance

T.4.7.4.3.3 Tubing, joints and seals

T.4.7.4.3.4 Provision for condensation

T.4.7.4.3.5 Conductivity of coolant

T.4.7.4.3.6 Leakage of coolant

Addition to 4.7.4.3.6:

Coolant released as the result of operation of a pressure relief mechanism must not be released into any electrical compartment.

T.4.8 *BDM/CDM/PDS* with multiple sources of supply

T.4.9 Protection against environmental stresses

T.4.9.1 General

Modification to 4.9.1:

1) Humidity, vibration, and UV resistance are not required to be declared.
2) Pollution degree is required when it is other than pollution degree 3, see T.4.4.7.1.3 1).
3) Ambient temperature is required when it is other than 40 °C.
4) Table 20 is not applicable.

T.4.10 Protection against excessive acoustic noise hazards

4.10 is not applicable.

T.4.11 Wiring and connections

T.4.11.1 General

Addition to 4.11.1:

1) Conductors must be not smaller than No. 24 AWG, and the temperature rating must be not less than 90 °C unless investigation proves the suitability of other conductors.

The requirements of T.4.11.1 apply only to the wiring furnished as a part of the *BDM/CDM/PDS*. They do not apply to the supply wiring run to *BDM/CDM/PDS*, to motors, or to other apparatus

The use of Table T.8 and Table T.9 as a guide in selecting the conductor sizes in *BDM/CDM/PDS* can obviate the need to perform a temperature test on the wire. Conductor sizes for other applications (e.g., heating loads) are subject to investigation.

Table T.8 – Allowable ampacities of insulated copper conductors inside industrial control equipment *enclosure*s (based on a *ambient temperature* of 40 °C)

Conductor size	Conductors with 90 °C *insulation*		Conductors with 105 °C *insulation*	
AWG or kcmil	Non-ventilated *enclosure*	Open or in ventilated *enclosure*	Non-ventilated *enclosure*	Open or in ventilated *enclosure*
24 22 20	1 2 3	2 3 4	1 2 3	2 3 4
18 16 14	4 6 9	6 9 13	4 6 10	6 9 15
12 10 8	12 18 31	17 27 47	15 22 35	22 35 55
6 4 3	45 61 70	67 91 104	52 71 80	80 108 121
2 1 0	80 94 110	120 141 164	90 107 133	140 164 190
00 000 0000	128 148 173	191 221 258	148 171 200	221 257 300
250 300 350 400 500	194 214 242 262 298	285 322 355 385 442	221 250 276 299 343	340 384 420 449 515

Table T.9 – Ampacity correction factors for multiple conductor groupings

Number of conductors	Correction factor
1 to 3	1,00
4 to 6	0,80
7 to 24	0,70
25 to 42	0,60
43 and more	0,50

2) Conductors smaller than No. 24 AWG may be used for wiring of printed circuit boards and interconnecting wiring between electronic modules and sub-assemblies.

3) Wiring spaces for field wiring must have, clear of all obstructions, a cross-sectional area of not less than 250 % of the total cross-sectional area of the maximum number of wires intended to be installed in it, and the minimum width or depth must be not less than specified in Table T.10.

Table T.10 – Wiring space

Maximum size of wire AWG/kcmil	**Minimum width or depth of wiring space** mm
10 and smaller	Not specified
8	12
6	15
4	19
3	19
2	22
1	25
0	25
00	25
000	28
0000	31
250	34
300	38
350	38
400	41
500	44
600	47
700	50
750	50
800	54
900	57
1 000	57
1 250	63
1 500	70
1 750	73
2 000	79

4) The wire sizes specified in Table T.11 and Table T.14 must be determined as follows.
   a) For *BDM*/*CDM*/*PDS* rated in horsepower,
      i) the full-load motor-running current must be selected from Table T.12 or Table T.13,
      ii) the conductor ampacity must be selected from the applicable table of the Canadian Electrical Code, Part I, and
      iii) the wire size with 75 °C ampacity must be selected from Table 2 or Table 4 of the Canadian Electrical Code, Part I.
   b) For *BDM*/*CDM*/*PDS* rated in amperes, the conductor ampacity and wire size must be selected in accordance with T.4.11.1 4) ii) and T.4.11.1 4) iii).
   c) For *BDM*/*CDM*/*PDS* rated in amperes only, the wire size must be selected in accordance with T.4.11.1 4) iii).

Table T.11 – Wire-bending space

Wire size AWG/kcmil	**Minimum distance** mm			
	Wires per terminal			
	1	**2**	**3**	**4 or more**
10 and smaller	Not specified	—	—	—
8	38	—	—	—
6	38	—	—	—
4	50	—	—	—
3	50	—	—	—
2	63	—	—	—
1	76	—	—	—
0	127	127	178	—
00	152	152	190	—
000	165 (152)	165 (152)	203	—
0000	177 (152)	177 (152)	216 (203)	—
250	203 (165)	203 (165)	228 (203)	254
300	254 (177)	254 (203)	279 (254)	304
350	305 (228)	305 (228)	330 (254)	355 (304)
400	305 (254)	305 (254)	355 (279)	381 (304)
500	305 (279)	305 (279)	355 (305)	406 (330)
600	355 (305)	406 (330)	457 (381)	482 (406)
700	355 (330)	406 (381)	457 (432)	482 (457)
750	457 (355)	482 (406)	558 (482)	609 (533)
800	457	482	558	609
900	457	482	609	609
1 000	508	—	—	—
1 250	558	—	—	—
1 500 to 2 000	609	—	—	—

Table T.12 – Full-load motor-running currents in amperes corresponding to AC horsepower ratings

Horse-power	110 V to 120 V			220 V to 240 V[a]			440 V to 480 V			550 V to 600 V		
	Single-phase	2-phase	3-phase	Single-phase	2-phase	3-phase	Single-phase	2-phase	3-phase	Single-phase	2-phase	3-phase
1/10	3	—	—	1,5	—	—	—	—	—	—	—	—
1/8	3,8	—	—	1,9	—	—	—	—	—	—	—	—
1/6	4,4	—	—	2,2	—	—	—	—	—	—	—	—
1/4	5,8	—	—	2,9	—	—	—	—	—	—	—	—
1/3	7,2	—	—	3,6	—	—	—	—	—	—	—	—
1/2	9,8	4	4.4	4,9	2	2,2	2,5	1	1	2	0.8	0,9
3/4	13,8	4,8	6.4	6,9	2,4	3,2	3,5	1,2	1,4	2,8	1	1,3
1	16	6,4	8.4	8	3,2	4,2	4	1,6	1,8	3,2	1,3	1,7
1-1/2	20	9	12	10	4,5	6,0	5	2,3	2,6	4	1,8	2,4
2	24	11,8	13.6	12	5,9	6,8	6	3	3,4	4,8	2,4	2,7
3	34	16,6	19,2	17	8,3	9,6	8,5	4,2	4,8	6,8	3,3	3,9
5	56	26,4	30,4	28	13,2	15,2	14	6,6	7,6	11,2	5,3	6,1
7-1/2	80	38	44	40	19	22	21	9	11	16	8	9
10	100	48	56	50	24	28	26	12	14	20	10	11
15	135	72	84	—	36	42	34	18	21	27	14	17
20	—	94	108	—	47	54	44	23	27	35	19	22
25	—	118	136	—	59	68	55	29	34	44	24	27
30	—	138	160	—	69	80	68	35	40	54	28	32
40	—	180	208	—	90	104	88	45	52	70	36	41
50	—	226	260	—	113	130	108	56	65	86	45	52
60	—	—	—	—	133	154	—	67	77	—	53	62
75	—	—	—	—	166	192	—	83	96	—	66	77
100	—	—	—	—	218	248	—	109	124	—	87	99
125	—	—	—	—	—	312	—	135	156	—	108	125
150	—	—	—	—	—	360	—	156	180	—	125	144
200	—	—	—	—	—	480	—	208	240	—	167	192
250	—	—	—	—	—	604	—	—	302	—	—	242
300	—	—	—	—	—	722	—	—	361	—	—	289
350	—	—	—	—	—	828	—	—	414	—	—	336
400	—	—	—	—	—	954	—	—	477	—	—	382
450	—	—	—	—	—	1 030	—	—	515	—	—	412
500	—	—	—	—	—	1 180	—	—	590	—	—	472

[a] To obtain full-load currents for 200 V and 208 V motors, increase corresponding 220 v to 240 V ratings by 15 % and 10 %, respectively.

Table T.13 – Full-load motor-running currents in amperes corresponding to DC horsepower ratings

Horsepower	90 V	110 V to 120 V	180 V	220 V to 240 V	500 V	550 V to 600 V
1/10	—	2,0	—	1,0	—	—
1/8	—	2,2	—	1,1	—	—
1/6	—	2,4	—	1,2	—	—
1/4[a]	4,0	3,1	2,0	1,6	—	—
1/3	5,2	4,1	2,6	2,0	—	—
1/2	6,8	5,4	3,4	2,7	—	—
3/4	9,6	7,6	4,8	3,8	—	1,6
1	12,2	9,5	6,1	4,7	—	2,0
1-1/2	—	13,2	8,3	6,6	—	2,7
2	—	17,0	10,8	8,5	—	3,6
3	—	25,0	16,0	12,2	—	5,2
5	—	40,0	27,0	20,0	—	8,3
7-1/2	—	58,0	—	29,0	13,6	12,2
10	—	76,0	—	38,0	18,0	16,0
15	—	110,0	—	55,0	27,0	24,0
20	—	148,0	—	72,0	34,0	31,0
25	—	184,0	—	89,0	43,0	38,0
30	—	220,0	—	106,0	51,0	46,0
40	—	292,0	—	140,0	67,0	61,0
50	—	360,0	—	173,0	83,0	75,0
60	—	—	—	206,0	99,0	90,0
75	—	—	—	255,0	123,0	111,0
100	—	—	—	341,0	164,0	148,0
125	—	—	—	425,0	205,0	185,0
150	—	—	—	506,0	246,0	222,0
200	—	—	—	675,0	330,0	294,0

[a] The full-load current for a 1/4 hp, 32 V DC motor is 8,6 A

T.4.11.2 *Insulation* of conductors

T.4.11.2.1 General

Addition to 4.11.2.1:

1) When insulating bus bars and bus joints are supplied, they must meet the following requriements.

   a) Bus joints, other than at shipping joints, must be completely covered by insulating materials at the factory. For interconnecting bus joints that must be made in the field, insulating material must be supplied for application in accordance with the manufacturer's instructions.

   b) A representative sample of insulated bus must withstand, without breakdown, the test for bus bar *insulation* specified in T.4.11.2 c) and d). This test must be conducted on one insulated bus bar test sample for each rated voltage.

c) The insulated bus bar sample must have the rated maximum voltage at rated power-frequency applied from the conductor to an electrode effectively covering the outer surface of the *insulation*, but sufficiently far from the ends of the sample to be able to withstand the test voltage.

d) The insulated bus bar sample must have a construction that is typical of bus bars, elbows, splices, and joints as used in the manufacturer's design. The test voltage must be applied for 1 min.

NOTE Suggested external electrodes are conductive paint, metallic foil, or the equivalent. Care should be taken to prevent the external *insulation* media from penetrating the test area between the sample *insulation* and the electrodes.

T.4.11.2.2 General

T.4.11.2.3 Accessible wiring *system*

Modification to 4.11.2.2:

IEC 61084 (all parts) and IEC 61386 (all parts) standards are not applicable.

T.4.11.3 Stranded wire

T.4.11.4 Routing and clamping

Addition to 4.11.4:

1) Wires must be supported, secured, or otherwise run in suitable raceways, so they do not come into contact with moving parts or rest on sharp edges or projections that can cause abrasion of the *insulation*. Wires must be of flexible or extra-flexible construction where they make connection to electrical equipment mounted on a hinged *door*. If the flexing section of the wiring is liable to come in contact with grounded metal parts, that portion of the wiring must be given additional protection with wrappings of tape or the equivalent, or must be enclosed in non-metallic flexible tubing or conduit.
2) A wire that is subject to flexing when a *door* is opened must
   a) be stranded and, if larger than 6 AWG, must have copper conductors of the extra flexible type, and
   b) be so cabled, routed, secured, and protected that the wire will not be damaged during opening and closing of the *door*.
3) If conductors greater than No. 10 AWG of an alternating-current circuit pass through a metal wall or partition having magnetic properties, all of the conductors of the circuit, including the neutral, must be run through the same opening. The conductors may pass through individual openings in a wall or partition of metal having magnetic properties if
   a) the openings are connected by slots cut in the metal wall, or
   b) during the temperature test of S.5.2.3.10, temperatures are recorded on interposed metal to determine that conductor *insulation* is not adversely affected. The conductors may be run through individual openings in an insulating block used to cover an opening in the metal wall sufficiently large for all the conductors of the circuit if no metal bracket, brace, or the like, is placed across the insulating material between the conductors. See Figure T.1.

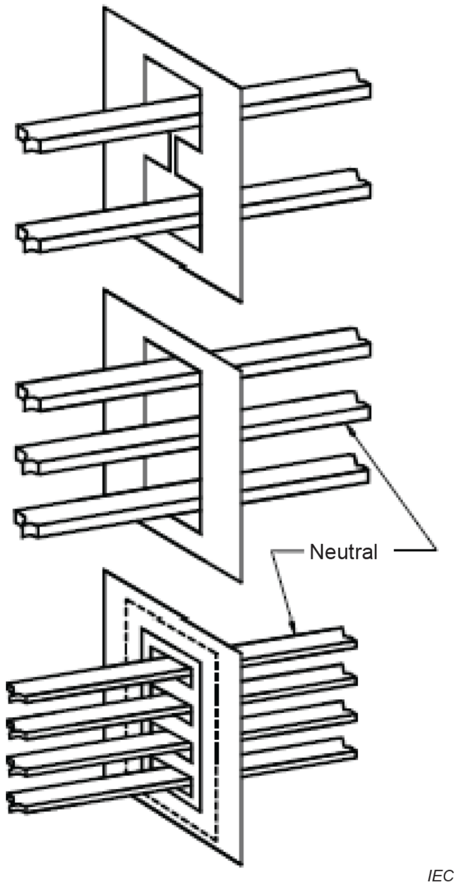


Figure T.1 – Routing conductors through a metal barrier

Table T.14 – Wire-bending space

Wire size AWG/kcmil	**Minimum distance** mm				
	Wires per terminal				
	1	**2**	**3**	**4**	**5**
14 to 10	Not specified				
8 to 6	38	—	—	—	—
4 to 3	50	—	—	—	—
2	63	—	—	—	—
1	76	—	—	—	—
0 to 00	88	127	177	—	—
000 to 0000	101	152	203	—	—
250	114	152	203	254	—
300 to 350	127	203	254	304	—
400 to 500	152	203	254	304	355
600 to 700	203	254	304	355	406
750 to 900	203	304	355	406	457
1 000 to 1 250	254	—	—	—	—
1 500 to 2 000	304	—	—	—	—

T.4.11.5 Identification of conductors and terminals of *mains supply* and *non-mains supply*

Modification to 4.11.5:

The identification of conductors and terminals for *protective equipotential bonding* and *PE conductor*s, including but not limited to color and symbols, must comply with CSA C22.2 No. 0.4.

T.4.11.6 Splices and connections

T.4.11.7 Accessible connections

T.4.11.8 Interconnections between parts of the *PDS*

Modification to 4.11.8:

1) IEC 60364 (all parts) is not applicable and replaced with CSA C22.1 CE code Part I;
2) IEC 60204-1:2016 is not applicable and replaced with CSA C22.2 No.14 and CSA C22.2 No.301.

T.4.11.9 Supply connections for *permanently connected BDM/CDM/PDS*

Additional subclause to 4.11.9:

T.4.11.9.200 Supply connections

1) A *BDM/CDM/PDS* must have provision for connection to the applicable wiring *system* in accordance with the requirements of the Canadian Electrical Code, Part I.
2) A tapped hole for the attachment of threaded rigid conduit must comply with the requirements of CSA C22.2 No. 0.5.
3) Knockouts must comply with the requirements of CSA C22.2 No. 0.
4) Except as provided for by T.4.11.200, *BDM*/*CDM*/*PDS* must be provided with wiring terminals or leads for the connection of conductors with an ampacity not less than the largest of the following:
   a) the ampere rating of the device;
   b) 125 % of the full-load motor-running current specified in Table T.12 or Table T.13 for the horsepower rating;
   c) 125 % of the resistive ampere rating of the devices intended to control fixed electric space-heating equipment loads; or
   d) 135 % of the nominal capacitive current rating of the devices intended to switch capacitors for power factor correction.
5) A *BDM/CDM/PDS* with a current rating or horsepower rating with a full-load motor-running current, as specified in Table T.12 or Table T.13, must be connected with wire of a size determined in accordance with Table 2 of the Canadian Electrical Code, Part I. The size must be based on wire suitable for a temperature of 60 °C for a rating of 100 A or less and on wire suitable for 75 °C for a rating greater than 100 A. The type of *insulation* is not specified.
6) A lead that is intended to be spliced in the field to a circuit conductor must be not smaller than No. 18 AWG. The *insulation*, if of rubber or thermoplastic, must be not less than 0,8 mm thick.

T.4.11.10 Supply connections for pluggable *BDM/CDM/PDS*

T.4.11.11 Terminals

T.4.11.11.1 Construction requirements

Addition to 4.11.11.1:

1) Terminal parts for *field wiring* connections must conform to the requirements of CSA C22.2 No. 0, except that
   a) ferrous binding head screws, bolts, studs, nuts, and washers may be used if suitably protected with a plating of zinc or equivalent material with a thickness not less than 0,005 mm, and
   b) for a No. 10 AWG or smaller conductor, the terminal to which wiring connections are made may consist of clamps or binding screws with a terminal plate having upturned lugs or the equivalent to hold the wires in position.

   See Table T.15 for terminal requirements.
2) A wire-binding screw to which field wiring connections are made must not be smaller than No. 8. However, a No. 5 screw may be used at a terminal intended only for connection of a No. 14 AWG or smaller conductor. A No. 6 screw must be used at a terminal intended only for connection of a No. 12 AWG or smaller conductor.
3) A terminal plate tapped for a wire-binding screw must be of metal not less than 0,75 mm thick for a No. 14 AWG or smaller wire, and not less than 1,25 mm thick for a wire larger than No. 14 AWG. There must be no fewer than two full threads in the plate. However, two full threads must not be required if fewer threads result in a secure connection in which the threads will not strip upon application of a 2,3 Nm tightening torque.
4) A terminal plate formed from stock with the minimum required thickness specified in T.4.11.11.1 3) may have the metal extruded at the tapped hole for the binding screw to provide two full threads.
5) Terminals of resistors used in the secondary circuits of wound-rotor induction motors, and in the armature circuits of DC shunt motors, must be suitable for the attachment of the conductors specified in Table T.16.
6) IEC 60947-7 (all parts) are not applicable, replaced by CSA C22.2 No.60947-7 series standards.

Table T.15 – Test values for *BDM/CDM/PDS* wiring terminals

Size of conductor AWG/kcmil	**Pullout force** N	
	Copper	**Aluminum or copper-clad aluminum**
22	20	—
20	30	—
18	30	—
16	40	—
14	50	—
12	60	44
10	80	44
8	90	44
6	94	124
4	133	160
3	156	187
2	186	222
1	236	271

Size of conductor AWG/kcmil	**Pullout force** N	
	Copper	**Aluminum or copper-clad aluminum**
0	285	320
00	285	347
000	351	432
0000	427	516
250	427	516
300	441	516
350	503	574
400	503	574
500	578	685
600	578	685
700	645	796
800	690	796
900	702	805
1 000	778	885
1 250	985	1 116
1 500	1 174	1 343
1 750	1 347	1 521
2 000	1 521	1 699

Table T.16 – Ampacity of conductors based on resistor duty cycle ratings

Duty cycle	Resistor[a] classification no.[b, c]	Ampacity of conductors in per cent of full-load armature or secondary currents
5 s ON 75 s OFF	101 to 106 111 to 116	35
10 s ON 70 s OFF	131 to 136	45
15 s ON 75 s OFF	141 to 146	55
15 s ON 45 s OFF	151 to 156 151P to 154P 152DL and 153 DL	65
15 s ON 30 s OFF	161 to 166 161P to 164P 162DL and 163DL	75
15 s ON 15 s OFF	171 to 176 171P to 174P 172DL and 173DL	90
Continuous duty	91 to 96 91P to 94P 92DL and 93DL	110

[a] Taken from EEMAC E14-2, Part ICS2-213, "Resistors and Rheostats".

[b] Classification numbers that include the letter "P" are for plugging service and the letters "DL" are for dynamic lowering.

[c] Classification numbers may be followed by the suffix "AS" denoting armature shunt or "DB" meaning dynamic braking resistor.

T.4.11.11.1 Construction requirements

T.4.11.11.2 Connecting capacity of terminals

Replacement of 4.11.11.2 with T.4.11.9.200 4).

T.4.11.11.3 Connection to external conductors

T.4.11.11.4 Wire bending space for wires 10 mm2 and greater

Addition to 4.11.11.4:

Wire-bending space at *field wiring terminal*s of enclosed *BDM/CDM/PDS* rated 750 V or less must comply with the following requirements, as applicable.

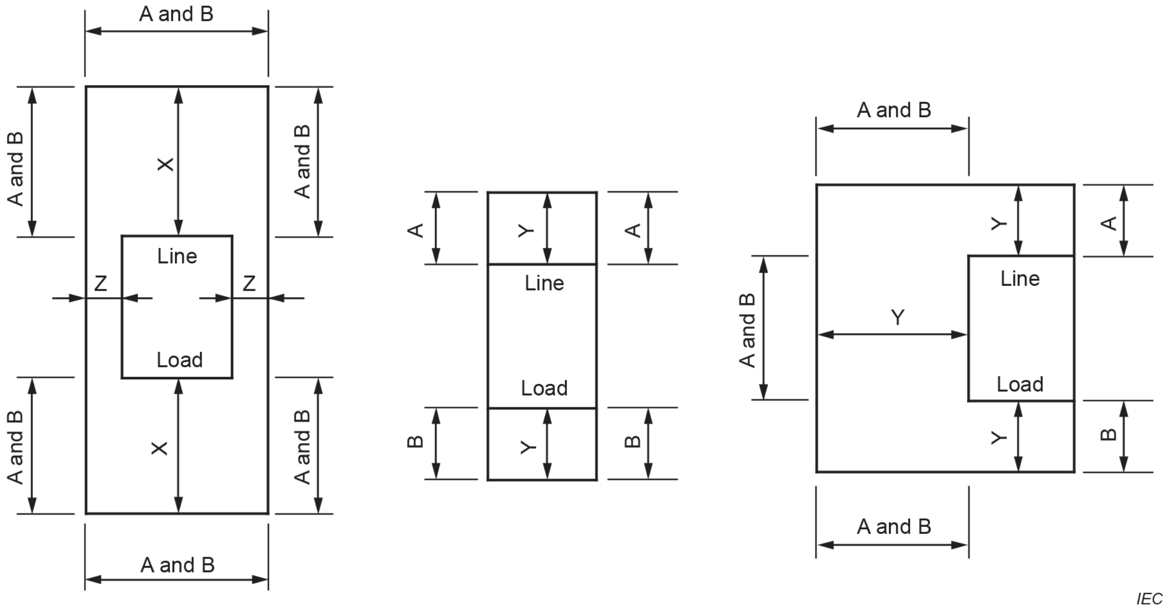
Where it is intended that a conductor enter or leave the *enclosure* through the wall opposite the terminal or pass through a barrier or other obstruction, the distance must be not less than that specified in Table T.11.

Where it is intended that a conductor not enter or leave the *enclosure* through the wall opposite the terminal, and where the conductor is deflected by the wall, a barrier, or other obstruction, the distance must be not less than that specified in Table T.14.

Additional subclause to 4.11.11.4:

T.4.11.11.4.200 Wire bending space (informative)

Figure T.2 shows some examples of the application of the requirements specified in this document.



Key

X wire-bending space in accordance with Table T.11

Y wire-bending space in accordance with Table T.14

Z wiring space in accordance with Table T.10

A section of *enclosure* perimeter where *mains supply* wires may enter

B section of *enclosure* perimeter where load wires may enter

Figure T.2 – Wire bending space

T.4.11.12 Provisions for connecting the shield of shielded wire or cable

Additional subclause to 4.11:

T.4.11.200 Field-installed *accessories* and kits

1) General
   a) Clause T.4.11.200 must apply to *accessories* designed for field installation in *BDM/CDM/PDS*.
   b) Clause T.4.11.200 must also apply, as appropriate, to field installation of *accessories* in *BDM/CDM/PDS*.
2) Wire connector kits and grounding kits
   a) *BDM/CDM/PDS* intended to be terminated with field wiring larger than No. 10 AWG need not have the wire connectors attached if connector and grounding kits that will properly accommodate conductors suitable for the ampere rating of the device are made available by the *BDM/CDM/PDS* manufacturer. Grounding kits may be provided for all sizes of conductors.
   b) The wire connector kits and grounding kits (in the form of either individual terminals or an assembly) must be so constructed that
      i) installation can be easily accomplished without the use of special tools,
      ii) *live part*s are suitably supported after being assembled,
      iii) reliable connections to terminal pads will be afforded,
      iv) the grounding terminal means are readily accessible when the *BDM/CDM/PDS* is mounted as in service and are not connected directly to a neutral (when provided),

v) each kit can be installed without disassembly of factory-assembled parts (other than those parts normally assembled for installation and wiring), and

vi) with the kit installed, *clearance* and *creepage distances* will be maintained.

3) Other kits

a) *BDM/CDM/PDS* must be suitable for use with or without such kits.

b) Each kit must be acceptable for the intended use and, when installed in the intended manner, must comply with all applicable requirements of this document.

c) Each kit must be capable of being installed without the use of a special tool, unless such a tool and instructions for its use are provided with each kit.

d) A barrier that is necessary because *clearance* and *creepage distances* would otherwise be less than required or for any other reason must be securely attached to either the kit or the *BDM/CDM/PDS*.

4) Markings for kits must be as described in T.6.2.2.200.

T.4.12 Mechanical requirements for *enclosures*

T.4.12.1 General

Replacement of 4.12.1:

1) *Enclosures* must be suitable for use in their intended environments. The manufacturer must specify the type rating of the *enclosure* in accordance with the requirements of CSA C22.2 No. 94.2. The manufacturer may add a supplemental IP designation to the required type designation, per the specifications of CSA C22.2 No. 60529.
2) *BDM/CDM/PDS* supplied with and located in walk-in *enclosures* must comply with the working *clearance* requirements of the Canadian Electrical Code, Part I. *BDM/CDM/PDS* with incomplete or partial *enclosures* must be evaluated as open devices in accordance with the performance requirements of this document.
3) Provisions for mounting must be made for securely mounting *BDM/CDM/PDS* to a supporting surface. A bolt, screw, or other part used to mount a *component* of the *BDM/CDM/PDS* must not be used for securing the complete device to the supporting surface. Panel-mounted devices that can be handled under normal operating conditions, such as switches and rheostats, must be staked or otherwise prevented from rotating. Such devices that rely solely on friction must not be considered acceptable.
4) Other than *BDM/CDM/PDS* designed to be free standing, provision must be made for securely mounting *BDM/CDM/PDS* to a supporting surface.
5) Coverings may be omitted from the bottom of a type 1, 2, or 3R floor-mounted *enclosure* if

a) the *enclosure* extends to the floor, with *live part*s mounted in the *enclosure* in accordance with 4.4.7.4 and 4.4.7.5,

b) *BDM/CDM/PDS* is rated 750 V or less,

c) the *enclosure* is within 150 mm of the floor, and

d) bare *live part*s of the device are not less than 150 mm above the lower edge of the *enclosure.*

T.4.12.2 Handles and manual controls

T.4.12.3 Cast metal *enclosure*

Replacement of 4.12.3:

A cast-metal *enclosure* of malleable iron and die-cast metal or permanent mould-cast aluminum, brass, bronze, or zinc must be not less than

a) 2,4 mm thick for an area greater than 15 500 mm^2 or having any dimension greater than 150 mm;

b) 1,6 mm thick for an area of 15 500 mm^2 or less, and having no dimension greater than 150 mm. The area limitation may be obtained by the provision of suitable reinforcing ribs subdividing a larger area; and

c) 3,2 mm thick at reinforcing ribs, *door* edges, and unthreaded conduit entries.

Thicknesses may be reduced if the *enclosure* complies with the requirements of the impact and conduit connection tests of 5.2.2.4.3 and T.5.2.2.200 1).

T.4.12.4 Sheet metal *enclosure*

Replacement of Table 22 and Table 23 with Table T.17 and Table T.18.

Addition to 4.12.4:

The thickness of sheet metal for *enclosure*s at points other than where a wiring system is to be connected needs not comply with the thickness requirements of 4.12.4 if the *enclosure* complies with the requirements in T.5.2.2.4.2 and T.5.2.2.202.

Table T.17 – Thickness of sheet metal for *enclosure*s – Carbon steel or stainless steel

Without supporting frame[a] cm		With supporting frame or equivalent reinforcement[a] cm		Minimum acceptable thickness mm	
Maximum width[b]	**Maximum length[c]**	**Maximum width[b]**	**Maximum length[c]**	**Uncoated**	**Metal-coated**
10,2 12,1	Not limited 14,6	15,9 17,1	Not limited 21,0	0,52	0,59
15,2 17,8	Not limited 22,2	24,1 25,4	Not limited 31,8	0,68	0,75
20,3 22,9	Not limited 29,2	30,5 33,0	Not limited 40,6	0,78	0,88
31,8 35,6	Not limited 45,7	49,5 53,3	Not limited 63,5	1,02	1,16
45,7 50,8	Not limited 63,5	68,6 73,7	Not limited 91,4	1,34	1,43
55,9 63,5	Not limited 78,7	83,8 88,9	Not limited 109,2	1,52	1,62
63,5 73,7	Not limited 91,4	99,1 104,1	Not limited 129,5	1,69	1,79
83,8 96,5	Not limited 119,4	129,5 137,2	Not limited 167,6	2,00	2,14
10,7 119,4	Not limited 149,9	162,6 172,7	Not limited 213,4	2,30	2,47
132,1 152,4	Not limited 188,0	203,2 213,4	Not limited 261,6	2,73	2,85
160,0 185,4	Not limited 228,6	246,4 261,6	Not limited 322,6	3,11	3,23

[a] See 4.12.4.

[b] The width is the smaller dimension of a rectangular piece of sheet metal that is part of an *enclosure*. Adjacent surfaces of an *enclosure* may have supports in common and be made of a single sheet.

[c] "Not limited" applies only if the edge of the surface is flanged at least 12,7 mm or fastened to adjacent surfaces not normally removed in use.

Table T.18 – Thickness of sheet metal for *enclosure*s – Aluminum, copper, or brass

Without supporting frame[a] cm		With supporting frame or equivalent reinforcement[a] cm		Minimum acceptable thickness mm
Maximum width[b]	**Maximum length[c]**	**Maximum width[b]**	**Maximum length[c]**	
7,6 8,9	Not limited 10,2	17,8 21,6	Not limited 24,1	0,58
10,2 12,7	Not limited 15,2	25,4 26,7	Not limited 34,3	0,74
15,2 16,5	Not limited 20,3	35,6 38,1	Not limited 45,7	0,91
20,3 24,1	Not limited 29,2	48,3 53,3	Not limited 63,5	1,14
30,5 35,6	Not limited 40,6	71,1 76,2	Not limited 94,0	1,47
45,7 50,8	Not limited 63,4	106,7 114,3	Not limited 139,7	1,91
63,5 73,7	Not limited 91,4	152,4 162,6	Not limited 198,1	2,41
94,0 106,7	Not limited 134,6	221,0 236,2	Not limited 289,6	3,10
132,1 152,4	Not limited 188,0	312,4 330,2	Not limited 406,4	3,89

[a] See 4.12.4.

[b] The width is the smaller dimension of a rectangular piece of sheet metal that is part of an *enclosure*. Adjacent surfaces of an *enclosure* may have supports in common and be made of a single sheet.

[c] "Not limited" applies only if the edge of the surface is flanged at least 12.7 mm or fastened to adjacent surfaces not normally removed in use.

T.4.12.5 Stability for floor-standing *BDM/CDM/PDS*

T.4.12.6 Wiring strain relief

T.4.12.7 Polymeric *enclosure* stress relief

T.4.12.8 Internal condensation or accumulation of water

T.4.12.9 Polymeric outdoor *enclosure* ultra-violet (UV) resistance

Modification to 4.12.9:

Outdoor *enclosure* must be in accordance with the requirements in CSA C22.2 No. 94.2.

Additional subclauses to 4.12:

T.4.12.200 *Door*s, *cover*s, and similar parts of *enclosures*

1) Except as noted in T.4.12.200 2), a part of the *enclosure* (e.g., a *door*, *cover*, or tank) must be provided with means (e.g., latches, locks, *interlock*s, or screws) for firmly securing it in place. If bare *live part*s are exposed by opening such doors or covers, means requiring the use of a tool to open them or provision for locking them must be provided to secure them in the closed position.
2) A snap-on *cover* that gives access to bare *live part*s and does not have a separate tool-operated fastener – as described in T.4.12.200 1) – must be acceptable, provided that it has no apparent means for removal (e.g., an extending tab) and withstands the securement test specified in T.5.2.2.201.

3) *Enclosure*s that are required to be opened during normal operating conditions, causing exposure of bare *live part*s, must have
   a) *door*s hinged in such a way that the *door* will not come off inadvertently, and
   b) barriers installed to prevent contact with bare *live part*s during normal operating conditions.

   NOTE The replacement of fuses is not considered a normal operating condition with respect to *BDM/CDM/PDS*, but the resetting of overload devices, repeated adjustment of timers or switches, etc., are considered normal operating conditions.

4) A hinged *cover*, provided in accordance with the requirement in T.4.12.200 3), must be provided with a spring latch or catch or with a captive fastener. Such fasteners must be located or used in multiples in such a way that the *cover* is held closed over its entire length. A hinged *cover* more than 1 220 mm long on the hinged side must have at least a two-point latch operated by a single knob or handle, or must have two or more separate spring latches or captive fasteners.

T.4.12.201 Openings in *enclosures*

1) An *enclosure*, when installed, must have no openings, other than ventilating openings, that permit the entry of a rod with a diameter greater than 12,7 mm. Any such openings must comply with the following requirements.
2) *BDM/CDM/PDS* rated 1 500 V or less ventilating openings in an *enclosure* (including perforations, louvres, and openings protected by means of wire screening, expanded metal, or a perforated *cover*) must be of a size or shape in which no opening permits the entry of a rod with a diameter greater than 19 mm for circuits of 600 V or less and 12,7 mm for circuits of 601 V to 1500 V. The opening must also comply with the requirements of T.4.12.201 4), 5) and 6).
3) For *BDM/CDM/PDS* rated greater than 750 V, the following must apply:
   a) Ventilation openings, including perforations, louvers, and openings must be protected by means of wire screening, expanded metal, or a perforated *cover* that must not allow the entry of the rod as specified in T.4.11.200.
   b) Barriers must be provided behind all ventilating openings into *high-voltage* compartments. The barrier must be effectively secured in place and must block visibility of *live parts*.
   c) The diameter of the wires of a screen must be not less than 1,3 mm if the screen openings are 320 mm^2 or less in area, and must be not less than 2,06 mm for larger screen openings.
   d) Perforated sheet steel and sheet steel employed for expanded metal mesh must be not less than 1,07 mm thick for mesh openings or perforations 320 mm^2 or less in area, and must be not less than 2,03 mm thick for larger openings.
4) The size of the openings described in T.4.12.201 1), 3) and 4), or their location, or both must prevent the articulated finger probe, illustrated in Figure M.2, from contacting un*insulated live part*s. Enamelled wire must be considered an un*insulated live part*.
5) The finger probe specified in T.4.12.201 4) must be applied in any possible configuration, and after insertion through the opening, the configuration must be changed if necessary.
6) The finger probe specified in T.4.12.201 4) must be used only as a measuring instrument to judge the accessibility provided by the opening. It must not be used as an instrument to judge the strength of a material. The test finger must be applied with a force not greater than 11 N.
7) The diameter of the wires of a screen must be not less than 1,3 mm if the screen openings are 320 mm^2 or less in area, and must be not less than 2,06 mm for larger screen openings.

8) Perforated sheet steel and sheet steel employed for expanded metal mesh must be not less than 1,07 mm thick for mesh openings or perforations 320 mm^2 or less in area, and must be not less than 2,03 mm thick for larger openings. In a small device, where the indentation of a guard or *enclosure* will not alter the *clearance* between uninsulated, movable *live part*s and grounded metal so as to adversely affect the performance or reduce *clearance* and *creepage distances* below the minimum values specified in 4.4.7.4 and 4.4.7.5, expanded metal mesh not less than 0,51 mm thick may be employed, provided that the

   a) exposed mesh on any one side or surface of the device so protected has an area of not more than 46 500 mm² and has no dimension greater than 305 mm, or

   b) width of an opening so protected is not greater than 88 mm.

9) Glass covering an observation opening and forming a part of the *enclosure* must be reliably secured in such a way that it cannot be readily displaced in service and must provide mechanical protection for the enclosed parts. Glass covering an opening not more than 100 mm in any dimension must be not less than 1,4 mm thick, and glass covering an opening having no dimension greater than 305 mm must be not less than 2,92 mm thick. Glass used to cover larger openings must be of the clear safety type or wire-reinforced type.

10) Polymeric transparent materials covering an opening must withstand the applicable tests specified in T.5.2.2.4.200 and T.5.2.5.5.

11) Electrical equipment must be constructed in such a way that molten or flaming particles cannot fall to the surface in which the equipment is mounted on or over.

12) Notwithstanding T.4.12.201 11), floor-mounted equipment may be marked in accordance with T.6.3.5.200.

13) An internal *component* with a polymeric *enclosure* (e.g. a blower motor), accessible through openings in the *BDM/CDM/PDS enclosure* that are in accordance with T.4.6.4.2, must comply with the polymeric *enclosure* tests required in T.4.12.201 3).

14) When openings in the *BDM/CDM/PDS enclosure* expose a *component* such as a blower motor body (either metal or polymeric) to water or dust during testing conducted in accordance with CSA C22.2 No. 94.2, that *enclosure* must protect the *component* from exposure to water or dust. The ability of that *component enclosure* to provide protection must be determined both with and without the forced ventilation in operation.

15) *Enclosures* for *high-voltage BDM/CDM/PDS* must be metal.

16) If parts operating above 750 V are exposed when covers or *door*s are opened, a warning marking must also be provided in accordance with T.6.4.202 1).

17) *Door*s of compartments containing high-voltage *components* must be mechanically interlocked in accordance with T.4.4.10.

18) Covers of compartments containing high-voltage *components* must be bolted closed.

19) Where a *door* must be opened for maintenance of *BDM/CDM/PDS* or removal of drawout elements, *low-voltage* energized uninsulated *live part*s mounted on the *door* must be effectively guarded or enclosed to provide protection against unintentional contact.

20) *Low-voltage* compartments required to be opened during normal operating conditions, thus exposing bare *live part*s, must comply with T.4.12.200 3).

21) Windows for the observation of the isolating contacts must be clear safety glass or wire reinforced safety glass.

T.4.13 *Components*

T.4.13.1 *Components* general

Addition to 4.13.1:

Except as permitted by T.4.1 2), electrical components must comply with the applicable standards of the Canadian Electrical Code, Part II, insofar as they apply.

T.4.13.2 *Components* representing a fire hazard

T.4.13.3 *Components* being part of an *enclosure*

T.4.13.4 *Components* representing a mechanical hazard

T.4.13.5 Wound *components*

Modification to 4.13.5:

IEC 61558-1:2017 is not applicable.

T.4.13.6 Protective devices

Additional subclause to 4.13.6:

T.4.13.6.200 Protection and fuseholders

1) Wiring between the load side of the branch-circuit short-circuit protection and the *overcurrent* device must be wholly located within the *enclosure* and not greater than 3 m in length.
2) Any wiring connected to a printed wiring board where the wiring is wholly contained within the *enclosure* is not required to be additionally protected.
3) Secondary circuit conductors that are supplied from approved power supplies where the output is inherently limited must be sized for the maximum power supply output current and are not otherwise required to be protected.
4) When the *BDM/CDM/PDS* is provided with *overcurrent* protection, ground-fault protection, and motor running overload protection, it must be in accordance with the Canadian Electrical Code, Part I.
5) Conductors of *control circuit*s that are connected to the load side of the *BDM/CDM/PDS short-circuit protective device* (common control), and extend beyond the control equipment *enclosure*, must be protected against *overcurrent*, in accordance with their ampacities, by protective devices located within the *BDM/CDM/PDS*. Additional protection or additional marking is not required if the rating or setting of the intended motor branch-circuit *short-circuit protective device* is not more than 300 % of the ampacity (15 A minimum) of the *control circuit* conductors.
6) The *overcurrent* protection provided must have a short-circuit interrupting rating equal to or greater than the marked *prospective short-circuit current* rating of the *BDM/CDM/PDS*. When fuses are provided, they must be types permitted by Rule 14-212 of the Canadian Electrical Code, Part I.
7) The protective device need not be assembled as part of the *BDM/CDM/PDS* if the manufacturer makes available or specifies an *accessory* kit; and the *BDM/CDM/PDS* is marked in accordance with T.6.2.2.200.
8) *Control circuit* transformer protection
   a) Except as provided in T.4.13.6.200 8) b), the *control circuit* transformer primary and secondary windings must be protected by one or more of the following types of *overcurrent* protection:
      i) an individual *overcurrent* protective device or devices located in the primary circuit that are rated or set as specified in Table T.19. *Overcurrent* protective devices must be provided in each ungrounded conductor;
      ii) secondary circuit protection rated or set at not more than 125 % of the rated secondary current of the transformer, with the primary feeder circuit protection rated or set at not more than 250 % of the rated primary current of the transformer; or
      iii) a coordinated thermal overload protection arranged to interrupt the primary circuit, provided that the primary circuit overcurrent device is rated or set to open at a current of not more than

– 6 times the rated current of the transformer for transformers having not more than 6 % impedance; or

– 4 times the rated current of the transformer for transformers having more that 6 % but less than 10 % impedance.

NOTE 1 The 250 % rating specified in T.4.13.6.200 8) a) ii) does not apply to transformers that have rated primary current inputs of less than 2 A.

Table T.19 – Maximum acceptable rating of primary *overcurrent* device

Rating primary current A	**Maximum rating of *overcurrent* protective devices expressed as a percentage of transformer primary current rating**
Less than 2	500
2 to less than 9	167
9 or more	125[a]
[a] See T.4.13.6.200 8) c).	

b) Overcurrent protection need not be provided if the

i) transformer is approved as a Class 2 energy limited transformer,

ii) transformer is rated not more than 50 VA, is inherently protected, and is an integral part of the *BDM/CDM/PDS*,

iii) primary feeder circuit overcurrent device provides the required protection, or

iv) protection is provided by other means that comply with the Canadian Electrical Code, Part I.

c) If the rated secondary current of a transformer is 2 A or more, the current rating of the secondary overcurrent device may be as indicated in Table T.20.

If the rated primary current of the transformer is 9 A or more and 125 % of this current does not correspond to a standard rating of fuse or nonadjustable circuit-breaker, the next higher standard rating of protective device must be used.

Table T.20 – Minimum acceptable rating of secondary *overcurrent* device

Rating secondary current A	**Maximum rating of *overcurrent* protective devices expressed as a percentage of transformer secondary current rating**
Less than 9	167
9 or more	125[a]
[a] See T.4.13.6.200 8) c).	

d) A control transformer and its primary and secondary conductors may be protected by *overcurrent* devices located only in the primary circuit, provided that

i) the transformer is single phase and has only a two-wire (single voltage) secondary,

ii) the maximum value of an intended *overcurrent* device is determined in accordance with T.4.13.6.200 Clause 8) a), and

iii) the maximum value of an intended *overcurrent* device as determined in T.4.13.6.200 8) d) ii), does not exceed the value of an overcurrent device obtained from Table T.21 for the secondary conductor multiplied by the secondary-to-primary voltage of the transformer.

Table T.21 – *Overcurrent* protectivre device – Copper conductors

***Control circuit* wire size** AWG	**Maximum protective device rating** A
22	3
20	5
18	7
16	10
14	20
12	25
10	35

e) The same overcurrent protective device may be used for both control-circuit transformer protection and primary-circuit conductor protection where its rating satisfies each requirement.

f) Protective device for control transformers

   i) Except as permitted by T.4.13.6.200 8) f) ii), the protective device specified in T.4.13.6.200 6) must be a branch-circuit *overcurrent* protective device.

   ii) Supplementary protective devices may be used as follows.

      1) Supplementary fuses may be used in the secondary circuits of control transformers provided that the fuse is installed in a fuseholder and the controller is marked in accordance with 6.4.5.

      2) A supplementary protector of the industrial, *overcurrent* type may be used in the secondary circuits of control transformers, provided that the primary protection of the transformer is sized to provide the short-circuit protection required for the supplementary protector, when applicable.

      3) A supplementary protector of the industrial, *overcurrent* type may be used in the primary circuits of control transformers provided that the supplementary protector has a

         – short-circuit application code of U3,

         – a tripping current application code of TC3, and

         – an overload code of OL1.

g) Motor overload protection

   i) The *PDS* must be provided with overload protection for all the motors that are integral to the *PDS* as well as to the motor controlled by the *BDM/CDM*, according to Section 28 of the Canadian Electrical Code, Part I.

   ii) *BDM/CDM/PDS* must be supplied with one of the following methods of achieving motor overload protection:

      – a mechanical overload relay conforming to the appropriate requirements of CSA C22.2 No. 14; or

      – solid state overload protection conforming to 5.2.4.6.

   iii) *BDM/CDM/PDS* that are used with motors with thermal protection (i.e. either on or in the motors) that require *port*s with the *BDM/CDM/PDS* must have means to connect to the thermal protection.

   iv) Timed current limiting control must not be considered as equivalent to motor overload protection.

   v) DC *BDM/CDM/PDS* must not contain overcurrent protection in a motor field supply circuit unless the *BDM/CDM/PDS* have a detector that can

      – prevent over-speed upon field loss, and

– detect loss of field current or voltage.

h) Instantaneous-trip circuit breakers

i) An instantaneous-*trip* circuit breaker must comply with the applicable construction requirements of CSA C22.2 No. 5.

ii) The adjustable setting means of an instantaneous-*trip* circuit breaker or self-protected control device that is accessible without opening a *door* or removing a *cover* must be constructed, that a stop to limit the maximum setting can be installed. Directions for the installation of the stop must be included with the complete controller.

iii) Open-phase protection

When an open-phase protective device is provided, it must operate when power is lost in one conductor of a polyphase circuit to cause and maintain the interruption of power in all of the circuit. An open-phase protective device for an intermittently operated machine (that has a definitely limited travel and a limited time for continuous running) may function only to prevent the restarting of the motor when power is lost in one conductor to the motor. See 5.2.4.12 for testing.

iv) Phase reversal protection

When a phase-reversal protective device is provided, it must operate on the reversal of the phase rotation in a polyphase circuit to cause and maintain power interruption in all of the circuit.

i) Fuseholders

i) A fuseholder must be of the cartridge or plug-fuse type. A cartridge fuseholder must accept a supplementary fuse as described in T.4.13.6.200 8) f) ii) 1), or a branch-circuit fuse, whichever is intended to be used.

ii) The construction of *BDM/CDM/PDS* incorporating a fuseholder, and the location of fuses (the normal function of which requires renewal), must be such that fuses will be readily accessible when the switch contacts are open to allow replacement without exposure to any live part. The electrical arrangement of a single-throw switch must be such that, if properly connected, fuse terminals are dead when the switch contacts are open.

NOTE 2 A *control circuit* fuse does not require renewal as a normal function, provided that the fuse and *control circuit* load (other than a fixed *control circuit* load such as a pilot light) are within the same enclosure.

iii) The *clearance* and *creepage distances* at fuses and fuse holders, measured with the fuses in place, must be determined using fuses that have the maximum standard dimensions, and the *clearance* and *creepage distances* must be not less than those specified in 4.4.7.4 and 4.4.7.5 accordingly.

Table T.22 – *High-Voltage BDM/CDM/PDS* dielectric strength test values, kV

Voltage rating (kV)	Dielectric strength test (hipot)	Impulse test (BIL)	Corona extinction
1,2	4,7	8	0,9
2,4	7,4	14	1,8
3,6	10,1	20	2,7
4,16	11,36	23,11	3,5
7,2	18,2	40	5,5
12	29	60	9,1
13,8	32,15	64,91	10,5
14,4	33,2	66,55	10,75
18	39,5	76,54	14
27,6	56,3	104	19
34,5	68,38	121,3	26,5

T.4.14 Protection against electromagnetic fields

4.14 is not applicable.

T.5 Test requirements

T.5.1 General

T.5.1.1 Test objectives and classification

Modification to 5.1.1:

*Sample test*s are not applicable.

T.5.2 Test specifications

T.5.2.1 *Visual inspections* (*type test*, **routine test** *and* **sample** *test)*

T.5.2.2 Mechanical tests

T.5.2.2.1 *Clearances* and *creepage distances* test (*type test*)

T.5.2.2.2 Non-accessibility test (*type test*)

Additional new subclause to 5.2.2.2:

T.5.2.2.2.200 Non-accessibility test (*type test*)

Rod entry test for *BDM/CDM/PDS* rated 750 V or higher.

This test, which is conducted to determine accessibility of *live part*s, must be as follows.

1) When *live part*s are less than 102 mm from an opening, this test must be conducted by attempting to insert a rod with a diameter of 12,7 mm.
2) When *live part*s are 102 mm or more from an opening, this test must be conducted by attempting to insert a rod having a diameter of 19 mm.
3) The *BDM/CDM/PDS* must be considered to comply with these requirements if the rod cannot enter the opening.

T.5.2.2.3 Ingress protection test (IP rating) (*type test*)

Addition to 5.2.2.3:

When required by T.4.12.1 1), *BDM/CDM/PDS* other than general purpose indoor use must be tested according to CSA C22.2 No.94.2.

T.5.2.2.4 *Enclosure* integrity test (*type test*)

T.5.2.2.4.1 General

T.5.2.2.4.2 Deflection test (*type test*)

Addition to 5.2.2.4.2:

1) A drawn, embossed, flanged, or similarly strengthened *door*, front, or *cover* made of metal with a thickness less than that specified in Table T.17 and Table T.18 must not deflect inward more than 6,5 mm when a vertical force of 445 N is applied at any point on the *door*, front, or *cover*.
2) The force must be applied through a bar with a flat, square face 13 mm on an edge. The test must be conducted with the *door*, front, or *cover* mounted on the box in the intended manner, and the *enclosure* placed with its back on a flat, unyielding horizontal surface.

T.5.2.2.4.3 Impact test (*type test*)

Additional new subclause to 5.2.2.4:

T.5.2.2.4.200 Resistance to impact test on observation openings (*type test*)

1) The test must be conducted on a single sample at an *ambient temperature* between 10 °C and 40 °C.
2) The test must be conducted with an impact as follows:
   a) 7,0 J ± 0,2 J for materials relied upon for protection against electric shock, fire, or mechanical hazards; or
   b) 0,5 J for materials for applications other than those covered in a).
3) A single impact must be applied at right angles to the surface with the *BDM/CDM/PDS* in its normal position.
4) The impact must not cause any of the conditions specified in 5.2.2.4.1 a) to f) to occur.
5) The impact must be applied by a solid, smooth steel sphere, 50 mm ± 1 mm in diameter, weighing approximately 0,53 kg. For top surfaces, the steel sphere must be allowed to fall freely from rest through the distance required to cause it to strike the *enclosure* when the sphere has the specified energy. For surfaces other than the top, the steel sphere must be suspended by a fine wire and allowed to fall as a pendulum through the distance required to cause it to strike the surface with the specified impact, and the *enclosure* must be placed so that the surface to be tested is vertical and in the same vertical plane as the point of support of the pendulum.

T.5.2.2.5 Wall or ceiling mounted test (*type test*)

5.2.2.5 is not applicable.

T.5.2.2.6 Handles and manual control securement test (*type test*)

5.2.2.6 is not applicable.

T.5.2.2.7 Strain relief test (type test)

T.5.2.2.8 Isolating means and *interlock* integrity test (*type test*)

T.5.2.2.9 Acoustic noise test (*type test*)

5.2.2.9 is not applicable.

Additional subclauses to 5.2.2:

T.5.2.2.200 Conduit connections and bending test (*type test*)

1) A polymeric *enclosure* intended for connection to a rigid conduit *system* must withstand, without pulling apart or incurring damage such as cracking and breaking, the pullout test, torque test, and bending test specified in T.5.2.2.200 2), 3), 4) and 5). The torque test must not apply to an *enclosure* that is not provided with a preassembled hub and has instructions specifying that the hub is to be connected to the conduit before being connected to the *enclosure*.
2) The *enclosure* must be suspended by a length of rigid conduit installed in one wall of the *enclosure*. A direct pull of 890 N must be applied for 5 min to a length of conduit installed in the opposite wall.
3) The *enclosure* must be securely mounted as intended in service. The torque must be applied to a length of installed conduit in a direction that tightens the connection. The lever arm must be measured from the centre of the conduit. The tightening torque must be in accordance with Table T.23, except that an end-of-line *enclosure* need only be subjected to a tightening torque of 22 Nm.

   NOTE An end-of-line *enclosure* is an *enclosure* that is intended to be connected at the end of a run of conduit and that has only one 3/4 maximum trade size opening for the connection of conduit.
4) Bending
   a) A suitable length of conduit that is at least 300 mm long and of the proper size must be installed in
      i) the centre of the largest unreinforced surface, or
      ii) a hub or an opening, if provided as part of the *enclosure*. The *enclosure* must be securely mounted as intended in service, but positioned so that the installed conduit extends in a horizontal plane.

      The weight necessary to produce the desired bending moment when suspended from the end of the conduit must be determined from the following formula:

$$W = \frac{0{,}102 \times M - 0{,}5 \times C \times L}{L}$$

      where

      W is the weight to be hung at the end of the conduit, kg;

      M is the bending moment required, Nm;

      C is the weight of the conduit, kg;

      L is the length of the conduit from the wall of the enclosure to the point at which the weight is suspended, m.
   b) The bending moment for the test specified in T.5.2.2.200 4) a) must be as specified in Table T.24. If the *enclosure* surface can be installed in either a vertical or horizontal plane, the vertical bending moment value must be used. For an end-of-line *enclosure* (see T.5.2.2.200 3)), the bending moment need only be 16,9 Nm.
5) If knockouts are incorporated in the design of an *enclosure* made of polymeric material, they must remain in place when subjected to a force of 89 N applied at right angles by means of a mandrel with a 6,3 mm diameter flat end. The mandrel must be applied at the point most likely to cause movement of the knockout.

Table T.23 – Tightening torque for testing conduit hubs of polymeric *enclosure*s

Conduit trade size in	Tightening torque Nm
3/4 and smaller	90
1, 1-1/4, 1-1/2	113
2 and larger	181

Table T.24 – Bending moment

<table>
<tr><th rowspan="2">Normal mounting plane of enclosure surface</th><th rowspan="2">Conduit size</th><th colspan="2">Conduit bending moment
Nm</th></tr>
<tr><th>Metallic</th><th>Nonmetallic</th></tr>
<tr><td>Horizontal</td><td>All</td><td>34</td><td>34</td></tr>
<tr><td>Vertical</td><td>1/2–3/4
1 and up</td><td>34
68</td><td>34
34</td></tr>
<tr><td colspan="4">The test may be terminated prior to attaining the values specified if the deflection of the conduit exceeds 250 mm for a 3 m length of conduit.</td></tr>
</table>

T.5.2.2.201 Securement of snap-on covers test (*type test*)

A snap-on *cover*, as permitted by T.4.12.200 2), must withstand the following tests.

1) A *cover* that can be released from its securement by a squeezing force applied with one hand must not be released when a squeezing force of 62 N or less is applied at any two locations not more than 125 mm apart. The distance must be measured by a tape stretched tightly over that portion of the surface of the *cover* that would be encompassed by the palm of a hand. The test must be conducted in the as-received condition and after the *cover* has been removed and replaced 10 times.
2) A *cover* must not become disengaged from the *enclosure* when a direct pull of 62 N is applied by gripping the *cover* at any two convenient locations. The test must be conducted in the as-received condition and after the *cover* has been removed and replaced 10 times.
3) A *cover* must not be displaced when subjected to an impact force of 1,4 J applied to the accessible faces of the *cover* (one blow per face). The impact must be applied by a steel ball having a diameter of not less than 25 mm.

T.5.2.2.202 Compression test (*type test*)

As required in T.4.12.4, an *enclosure* constructed of metal that is thinner than that specified in Table T.17 and Table T.18 must be reinforced so that its deflection is not more than that of a reference sheet metal *enclosure* of the maximum length and width constructed of the minimum required sheet metal thickness.

The *enclosure* must rest on a flat, unyielding horizontal surface. A vertical force must be applied at any point on the surfaces of the *enclosure*, except for the *door* or *cover*, using a flat face of a steel bar with a 13 mm square cross-section. Force must be applied to the end, side, and rear walls of each *enclosure*. The value of force and limit of deflection, both of which must be measured and recorded, are not specified, but the force on each wall of both the test and reference *enclosures* must be sufficient to result in a measurable deflection on the test *enclosure*.

T.5.2.3 Electrical tests

T.5.2.3.1 General

T.5.2.3.2 *Impulse withstand voltage* test (*type test, sample test*)

Addition to 5.2.3.2:

1) A surge-controlled circuit must withstand, without breakdown, a single 1,2 μs by 50 μs full-wave impulse with a crest value of 5 000 V for *low-voltage BDM/CDM/PDS* and a BIL value in accordance with Table T.22 for *high-voltage BDM/CDM/PDS* (see ANSI/IEEE 4).
2) The *BDM/CDM/PDS* must be connected to a source of supply operating at rated voltage with the output of the impulse generator connected across the input phases of the *BDM/CDM/PDS*.
3) For *BDM/CDM/PDS* incorporating surge arrestor(s), the *impulse withstand voltage* test may be performed with surge arrestors in place. If the surge arrestor conducts before the crest voltage specified in T.5.2.3.2 1) is reached, the arrestor(s) must be removed from the circuit and the *impulse withstand voltage* test must be repeated using a crest voltage equal to or greater than the discharge voltage observed with arrestors in place.
4) Transient suppression devices (e.g., varistors or transient voltage surge protectors) must be evaluated in accordance with the *component* requirements in CSA C22.2 No. 269.5.

T.5.2.3.3 Alternative to *impulse withstand voltage* test (*type test, sample test*)

T.5.2.3.4 AC or DC voltage test (*type test, routine test*)

T.5.2.3.4.1 Purpose of test

T.5.2.3.4.2 Value and type of test voltage

Addition to 5.2.3.4.2:

1) *BDM/CDM/PDS* must withstand, for 1 min without breakdown, the application of a 50 Hz or 60 Hz essentially sinusoidal voltage of
   a) 500 V for devices rated 50 V or less,
   b) 1000 V plus twice the maximum rated voltage for devices rated at 51 to 750 V,
   c) 2000 V plus 2,25 times the rated voltage for devices rated at 751 to 1500 V, and
   d) as per Table T.22 for *high-voltage BDM/CDM/PDS*.
2) For *routine test* only, the test duration may be 1 s if the test voltage is 20 % greater than specified in T.5.2.3.4.2 1) a), b) or c).
3) If the test voltage is applied to evaluate *enhanced protection*, then the value of the test voltage must be in accordance with 5.2.3.4.2.
4) If *BDM/CDM/PDS* contains a meter or meters, such instruments may be disconnected from the circuit as specified in T.5.2.3.4.2 1). The meter or meters must then be tested separately for dielectric strength with an applied voltage of
   a) 1 000V AC plus twice the maximum rated voltage between the *low-voltage* power supply circuit and any exposed non-current-carrying metal parts,
   b) 1 000 V AC plus twice the maximum rated voltage between *live part*s of the *low-voltage* circuit and *live part*s of circuits operated at 50 V or less,
   c) 500 V AC between exposed non-current-carrying metal parts and circuits (including meters) operated at 50 V or less (no test requirements are specified for circuits operated at 30 V or less), and
   d) 2 000 V AC plus 2,25 times the maximum rated voltage for devices rated above 750 V applied between power supply circuits and any non-current-carrying metal parts.
5) If *BDM/CDM/PDS* contains printed wiring assemblies and other electronic circuit *components* that would be affected adversely by application of the test voltage (or that are

designed to protect the *BDM/CDM/PDS* from voltage), they must be removed, disconnected, or otherwise rendered inoperable before the dielectric tests are made. A representative sub-assembly may be tested instead of an entire unit. The *insulation* and *clearance* and *creepage distances* of circuits using these devices must then be tested separately for dielectric strength, with an applied voltage of

a) 1 000 V AC plus twice the maximum rated voltage between the *low-voltage* power supply circuit and any exposed non-current-carrying metal parts,

b) 1 000 V AC plus twice the maximum rated voltage between *live part*s of the *low-voltage* circuit and *live part*s of circuits operated at 50 V or less, and

c) 500 V AC between exposed non-current-carrying metal parts and circuits (including meters) operated at 50 V or less (no test requirements are specified for circuits operated at 30 V or less).

6) To determine whether *BDM/CDM/PDS* complies with the requirements of T.5.2.3.4.2 1) 2), the device must be tested by means of a suitable 500 VA or larger-capacity transformer, the output voltage of which is essentially sinusoidal and can be varied. The applied voltage must be increased from zero to the required value at a substantially uniform rate and as rapidly as is consistent with its value being correctly indicated by a voltmeter. The voltage must be held at that value for 1 min.

7) Where it is more convenient to do so, the dielectric strength test may be made by applying a DC voltage instead of an AC voltage, provided that the voltage used is 1,4 times the values specified in T.5.2.3.4.2 1).

T.5.2.3.4.3 Additional test considerations

T.5.2.3.4.4 Performing the voltage test

Addition to 5.2.3.4.4:

A transformer, a coil, an electronic device not used as an isolation device, or any similar device normally connected between phases of opposite polarity must be disconnected from one side of the phase during the test. To create a continuous circuit for the voltage test on the *BDM/CDM/PDS,* terminals, open contacts on switches and semiconductor switching devices, etc. must be bridged where necessary.

Before testing, semiconductors and other vulnerable *components* within a circuit may be disconnected and/or their terminals bridged to avoid damaging them during the test.

T.5.2.3.4.5 Duration of the AC or DC voltage test

Modification to 5.2.3.4.5:

The duration specified is not applicable and replaced with T.5.2.3.4.2 1) and 2).

T.5.2.3.5 Partial discharge test (*type test*, *sample test*)

Replacement of 5.2.3.5:

1) Corona testing is optional for *BDM/CDM/PDS* rated 15 000 V or less. The test for *high-voltage BDM/CDM/PDS* may be done on subassemblies, if it is not possible to perform the test on the entire *BDM/CDM/PDS*.

2) When corona-extinction tests are required, the maximum allowable corona pulse magnitude must be 100 pC when *BDM/CDM/PDS* are tested with the corona-extinction voltage specified in Table T.22.

NOTE See T.5.2.3.200 for guidance on the measurement of corona in *high-voltage BDM/CDM/PDS*.

Additional subclause to 5.2.3:

T.5.2.3.200 Guidelines to the measurement of corona in *BDM/CDM/PDS* (informative)

T.5.2.3.200.1 General

T.5.2.3.200 consolidates current information on the art of detecting corona discharge in *BDM/CDM components* and assemblies.

Corona inception and extinction voltages are important in the design of *insulation system*s. The presence of corona at operating voltage can result in a significant reduction in life in some *insulation* materials. Some are more susceptible to damage than others. Corona parameters, particularly corona pulse magnitude and repetition rate, influence the rate at which deterioration occurs. The corona detected, however, sometimes originates at a location, such as leads or terminals, where it does not significantly affect the *insulation* in the specimen. In general, corona is not a material characteristic, but a function of an *insulation system* including the electrodes.

Corona is influenced by environmental conditions such as temperature, atmospheric pressure, humidity, liquid immersion, and previous electrification. The corona extinction voltage is often substantially less than the inception voltage. Where the operating voltage is below the corona inception voltage but above the extinction voltage, an over-voltage can start corona, which then continues until the voltage has fallen below the extinction level.

T.5.2.3.200.2 Scope for the measurement of corona in *BDM/CDM/PDS*

1) T.5.2.3.200 covers the measurement, at power frequencies, of corona inception and extinction voltages as measured at the terminals of *BDM/CDM components* and assemblies.
2) Actual corona extinction voltage levels, discharge magnitudes, and points of application of test voltage are specified in T.5.2.3.5 and Table T.22.
3) T.5.2.3.200 is concerned with the practical determination of corona levels and not with the effect of corona on various *insulation* materials. Therefore, no attempt has been made to include references to energy levels, discharge currents, etc.

T.5.2.3.200.3 Definitions for the measurement of corona

In addition to the definitions in Clause 3 and Clause T.3, the following definitions must apply in T.5.2.3.200:

Corona – any discharge within the *insulation system* that does not result in complete breakdown.

Corona-free sample – a sample that has a corona extinction voltage 25 % above the CEV level specified for that voltage class.

Corona extinction voltage (CEV**)** – the applied RMS voltage at which corona above the specified magnitude is no longer observed as the voltage is decreased from above the corona inception voltage.

Corona inception voltage (CIV) – the lowest root-mean-square (RMS) applied voltage at which corona above the specified magnitude is observed to occur as the voltage is increased.

Discharge magnitude (of a partial discharge; often referred to as the apparent charge "q") – the charge that, if injected instantaneously between the terminals of the test object, would momentarily change the voltage between the terminals by the same amount as the partial discharge itself.

NOTE *The apparent charge "q"* so defined is not equal to the amount of charge actually transferred across the discharging cavity in the dielectric test. It is used because discharge-measuring instruments respond to this quantity.

T.5.2.3.200.4 Corona test conditions

1) The frequency of the supply voltage must be 60 Hz ± 5 %. A sine wave of acceptable commercial standard is preferred. Voltage readings must be made using a crest reading instrument and be expressed in equivalent RMS values, or the crest voltages divided by the square root of two.
2) Tests must be made only when the test equipment and environment are such that there are no observable indications of corona with the test sample replaced by a corona-free sample (with capacitance of the same order of magnitude as the test sample) and a test voltage applied that is 25 % above the specified corona extinction voltage.
3) Since the effects of atmospheric conditions are not known, there must be no corrections for abnormal temperature, humidity, or pressure, but it is recommended that
   a) tests be performed when the vapour pressure of moisture in air is between 0,2 in of mercury and 0,6 in of mercury,
   b) barometric pressure and wet-and-dry-bulb thermometer readings be recorded, and
   c) tests be performed when the *ambient temperature* is within the range of 15°C to 30 °C.
4) Temporary connections and leads must be shielded so as to prevent generation of corona on them, which would mask or prevent determination of corona during tests.

T.5.2.3.200.5 Corona test equipment

1) The basic test circuit must be as illustrated in Figure T.3. Alternatively, where appropriate, the test circuits illustrated in Figure T.4, Figure T.5 and Figure T.6 may be used.
2) The power source must meet the conditions of T.5.2.3.200.4 1) and 2). The source must have adequate capacity to supply the required charging kVA to the load of the sample and the coupling capacitor. The addition of filters to the input and output terminals of the source might be necessary to reduce external influences and minimize loss of corona signal.

   NOTE 1 kVA required = 0,377 x C x E^2 where C is in microfarads and E is in kilovolts.

3) The value of the bypass or coupling capacitor, C_{cc}, should be equal to or greater than the test specimen capacitance, C_t, and meet the conditions of T.5.2.3.200.4 2).
4) Calibration of test equipment
   a) A pulse generator must be connected to the specimen terminals to provide a pulse of suitable magnitude that reaches crest value in 0,1 µs or less and does not decay to less than half crest value in 1 ms.

      NOTE 2 A square-wave generator that meets these requirements is a satisfactory pulse source.

   b) Calibration of the circuit must be established by a calibrated instrument, which may be either an oscilloscope, square-wave generator, or other appropriate equipment.
   c) See Figure T.7 for curves showing typical test set sensitivity.
   d) Refer to Table T.25 for test circuit sensitivity equations.

T.5.2.3.200.6 Corona tests

1) Condition
   a) The test sample must be in the test environment for sufficient time to stabilize its temperature and humidity.
   b) The test sample must be clean and dry.
2) Connections
   a) The test sample must be connected in the circuit in conditions that are similar to its normally installed service environment with respect to its mounting arrangement, ground plane, and high-voltage connections.
   b) If secondary wiring is required, the leads must be brought off radially away from the body of the sample to a ground plane at a suitable distance.

c) For voltage transformers or control-power transformers of the phase-to-phase type, corona measurements for each of the following connections must be made:

i) test voltage applied to H1 and H2 linked, with X1, X2, and the base grounded.

ii) test voltage applied to H1, with H2, X2, and the base grounded.

iii) test voltage applied to H2, with H1, X2, and the base grounded.

NOTE The test specified in i) stresses the major *insulation* and the *insulation* of the primary windings and terminals to ground. The tests specified in ii) and iii) stress the turn and layer *insulation* in the primary windings and the primary terminals to ground.

d) For voltage transformers or control-power transformers of the phase-to-ground type, the corona measurements must be made with the test voltage applied to H1 with X2, H2, and the base grounded.

NOTE 1 This test stresses the turn and layer *insulation* in the primary winding and the H1 terminal to ground.

NOTE 2 In corona testing of a voltage transformer, the maximum voltage to be applied should be no more than 140 % of its primary accuracy rating voltage.

c) The test circuit for instrument transformers must be that shown in Figure T.3 or Figure T.4.

3) Test procedure

a) Voltage must be applied and raised to at least one-half the standard power frequency dielectric test voltage until corona starts, or for 1 min, and must then be reduced to the specified corona extinction voltage and held at this voltage for a period not exceeding 2 min. The equipment must be deemed to have passed the test if the observable corona above the specified magnitude has ceased within the final 2 min period.

b) If, at the end of the 2 min period, discharge indication is evident only in the form of spurious or random spikes spaced at least 2 s apart, then for the purposes of T.5.2.3.200, the corona above the specified magnitude must be considered as having ceased.

T.5.2.3.200.7 Corona testing sensitivity

1) Test set sensitivity

Instruments respond to voltage changes resulting from corona discharges within the test specimen.

For a given corona discharge magnitude, the voltage change is basically inversely proportional to the capacitance of the circuit. Therefore, with increased capacitance of the test specimen, increased gain or sensitivity will be required in the instrumentation to detect the same apparent corona discharge magnitude.

2) Test circuits

a) Circuits shown in Figure T.3 and Figure T.4 are recommended where it is convenient to have one electrode of the test sample grounded.

b) Circuits shown in Figure T.5 and Figure T.6 are suitable for test samples of small dimensions that can be easily isolated from ground.

3) Test circuit sensitivity formulas

The formulas listed in Table T.25 are based on the assumption that both the corona and calibration pulse voltages have a sufficient rate of rise, that their initial distribution throughout the circuit is controlled only by the circuit capacitances. Stray capacitance across the circuit element and its connection leads are in general considered part of the impedance of that element. Stray capacitance between the high-voltage lead and ground has been considered negligible in these expressions. However, it is suggested that, if maximum measurement accuracy is desired, stray capacitance be considered in accordance with ASTM D1868.

Table T.25 – Test circuit sensitivity formulas

$\frac{E_c}{H_c} \times C_c \frac{C_{cc} + C_t}{C_{cc}}$	**Formula T.1**
$\frac{E_c}{H_c} \times C_c$	**Formula T.2**
$\frac{E_c}{H_c} \times C_c \frac{(C_{cc} + C_t)}{C_{cc}}$	**Formula T.3**
$\frac{E_c}{H_c} \times C_t$	**Formula T.4**
where E_c is the crest voltage of calibrating pulse, V; H_c is the maximum deflection from normal trace produced by calibrating pulse, cm; C_t is the specimen capacitance, pF; C_c is the capacitance of coupling capacitor, pF; C_c is the capacitance of calibrating capacitor, pF.	

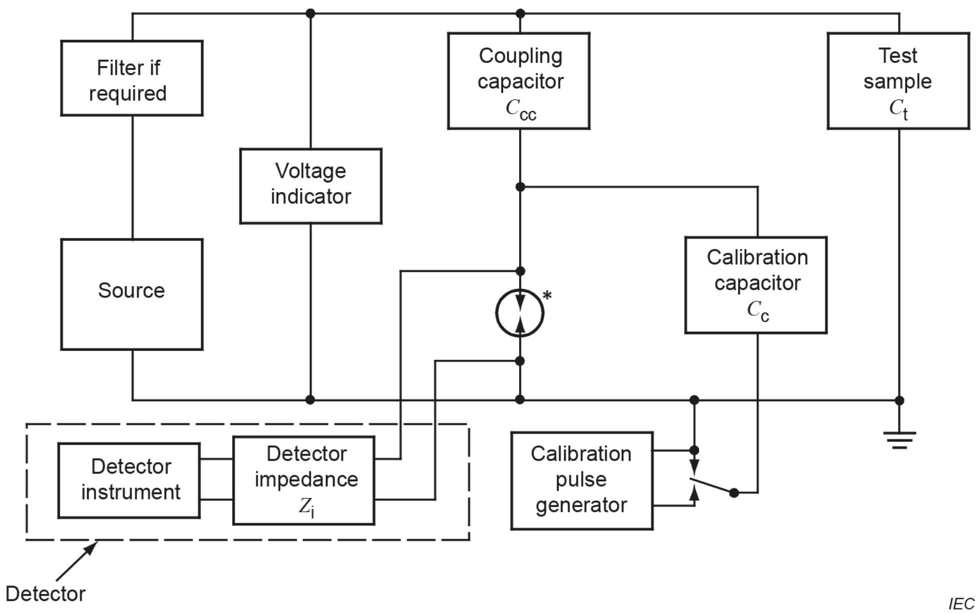


Figure T.3 – Test circuit using Formula T.1

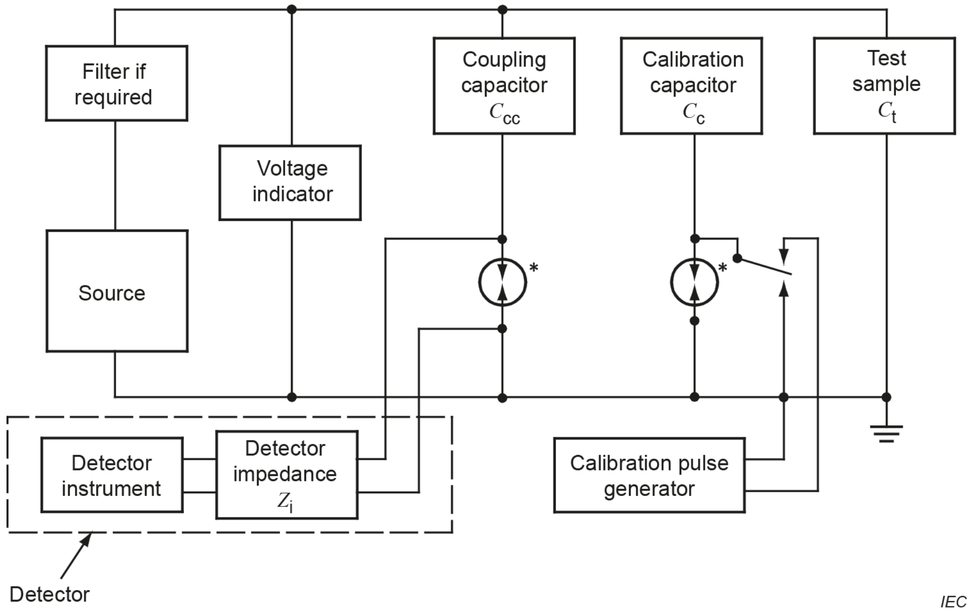


Figure T.4 – Test circuit using Formula T.2

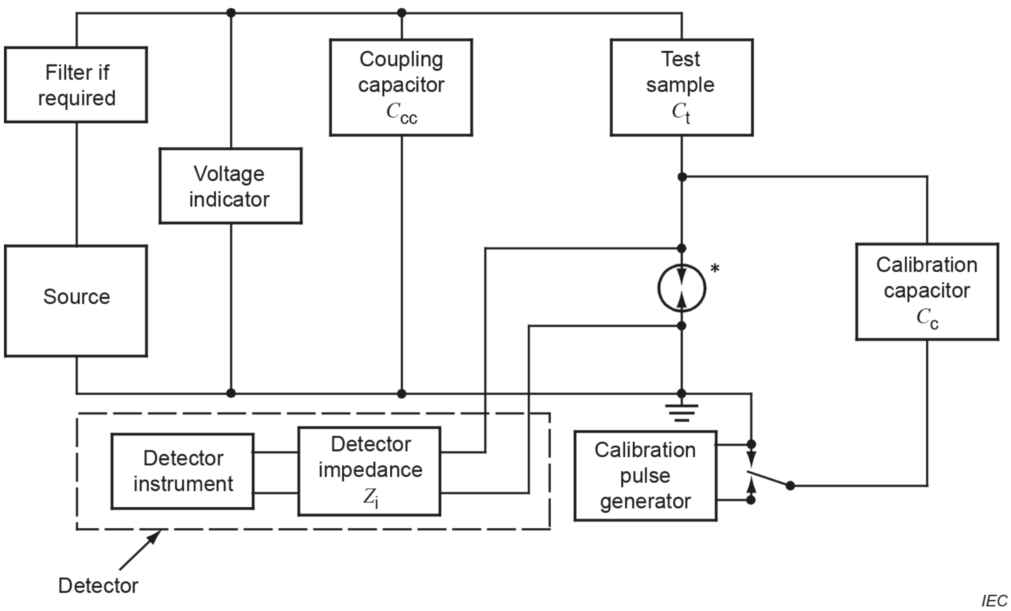


Figure T.5 – Test circuit using Formula T.3

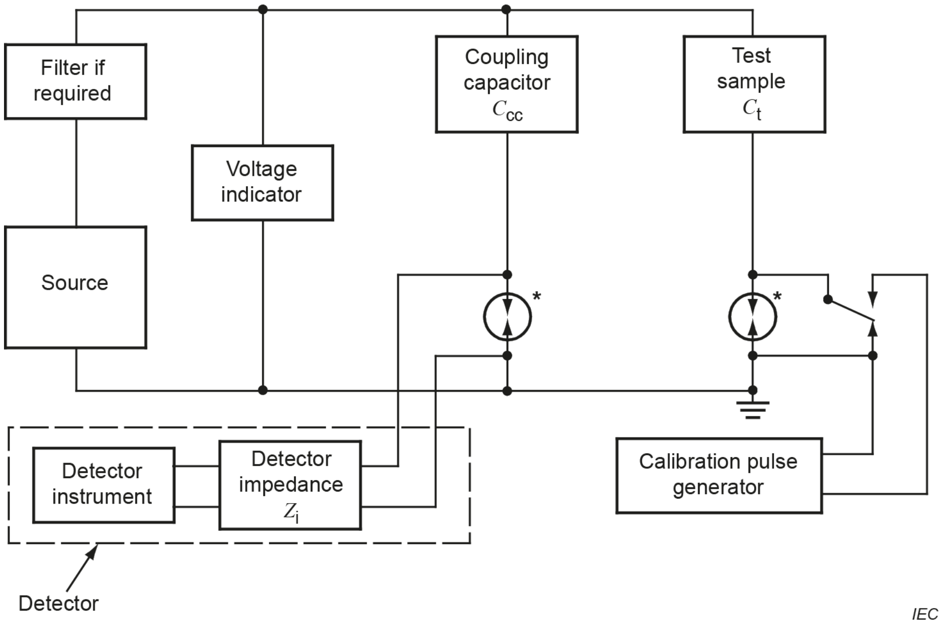


Figure T.6 – Test circuit using Formula T.4

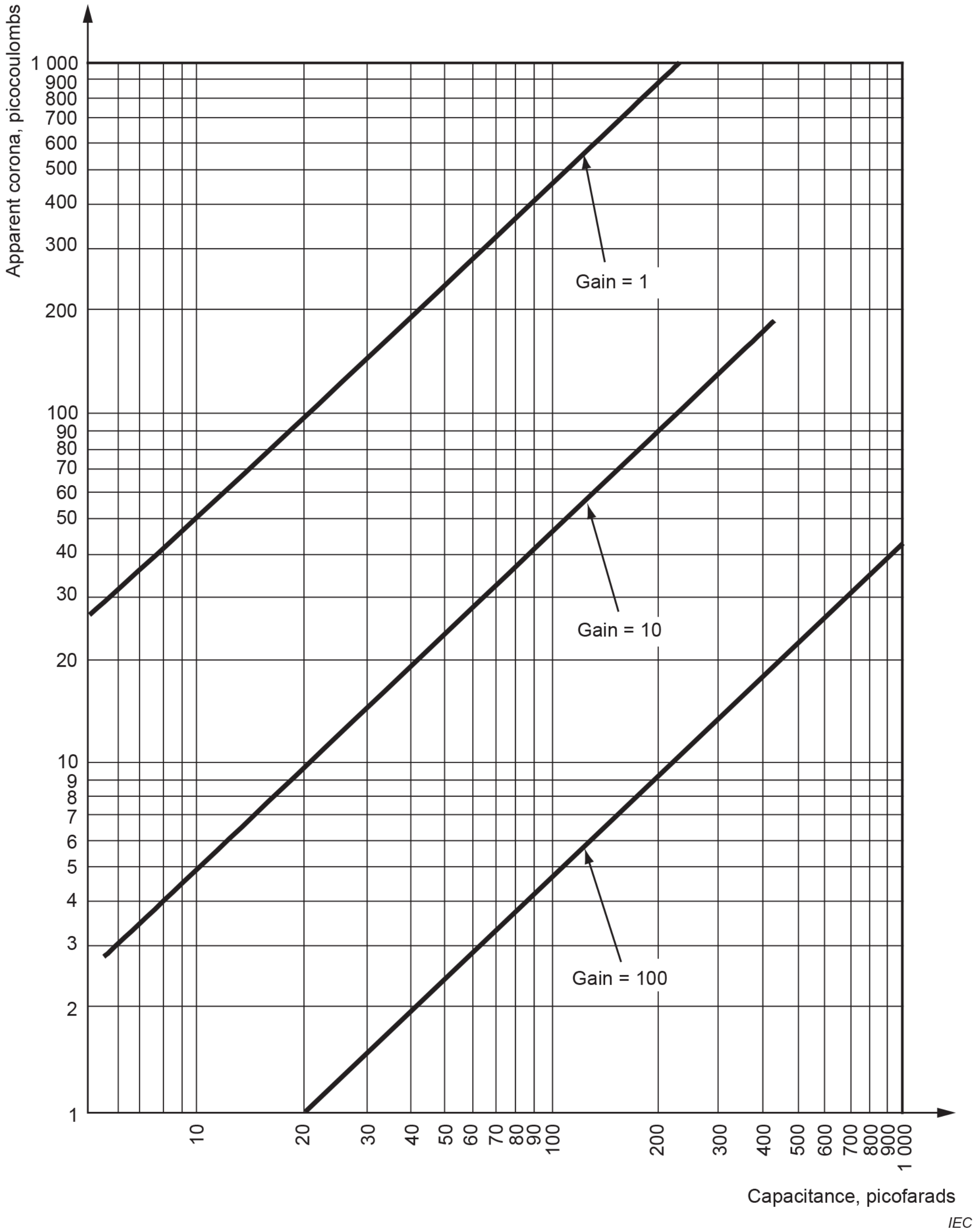


Figure T.7 – Typical test set sensitivity

T.5.2.3.6 *Protective impedance* test (*type test, routine test*)

T.5.2.3.7 *Touch current* measurement test (*type test*)

T.5.2.3.8 Capacitor discharge test (*type test*)

Modification to 5.2.3.8:

The option of "by calculation" is not applicable; it must be done by testing only.

T.5.2.3.9 Limited power source test (*type test*)

T.5.2.3.10 Temperature rise test (*type test*)

Addition to 5.2.3.10:

1) The *BDM/CDM/PDS* must carry its rated current until temperatures are constant as follows:
   a) for continuous operation, according to the continuous current ratings;
   b) for intermittent operation, according to the rated duty cycle.
2) For low-voltage *BDM/CDM/PDS*, tests must be performed at
   a) rated frequency,
   b) nominal (mains) voltage of 120 V, 208 V, 240 V, 277 V, 480 V, or 600 V, as applicable for the voltage ratings, and
   c) a voltage of 90 % to 110 % of the rated voltage if there is load current adjustment to generate the maximum normal heating.
3) For *high-voltage BDM*/*CDM*/*PDS*, the temperature test may be performed at rated voltage per Table T.22 or at any suitable voltage if there is a load current adjustment to generate the maximum normal heating.
4) An *open type BDM/CDM* must be placed in an *enclosure* similar to that of projected use. The maximum dimensions of the *enclosure* must be established by one of the following means:
   a) an *enclosure* measuring 150 % of the device measurements;
   b) an *enclosure* that complies with the wire-bending space in T.4.11.11.4.200;
   c) a standard outlet box; or
   d) a projected *enclosure*, greater in dimension that specified in T.5.2.3.10 4) a), b) and c) when indicated in the manufacturer's installation instructions.
5) The wiring used for testing must comply with the following.

   An *BDM/CDM/PDS* device must be tested at rated current with 1 220 mm of copper wire attached to each *field wiring terminal*.
   a) The wire must be of the smallest size, having an ampacity of at least 125 % of the test current for motor loads and at least 100 % for other loads.
   b) Wire size must be determined in accordance with Table T.26, based on the wire temperature rating marked on the *BDM/CDM/PDS*.
   c) The type of *insulation* is not specified, but the colour must be black. The temperature test may be performed with conductors *insulation* that is not black, but reference temperature measurements must be conducted with black insulated conductors.

   If the terminal will not receive the size of wire required for testing at rated current, the maximum allowable wire size must be used.
6) If there is provision only for the connection of busbars rated at 450 A or more, copper busbars must be used that are 6,4 mm thick, the width specified in Table T.27, and at least 1 220 mm in length. The busbars may be painted black. The *clearance* and *creepage distance* between multiple busbars must be 6,4 mm, with no intentional wide *clearance* and *creepage distance* except as necessary at the individual terminals of the *BDM/CDM/PDS*.
7) If reference measurements of *ambient temperature*s are necessary, several thermometers or thermocouples must be placed at different points around the *BDM/CDM/PDS* at a distance of 900 mm to 1 800 mm. The thermometers or thermocouples must be located in the path of the cooling medium, but protected from drafts and abnormal heat radiation. The *ambient temperature* must be the mean of the temperatures taken at equal time intervals during the final quarter of the test.
8) The suitability of *insulation* materials, other than those listed in Table 17, must be determined (with respect to properties such as flammability, arc resistance, etc. (see Table 17) based on an operating temperature of 40 °C plus the measured temperature rise.

9) Temperatures must be measured using a potentiometer-type instrument and thermocouples consisting of wires not larger than No. 30 AWG or, subject to investigation, not larger than No. 24 AWG.

10) The preferred method for measuring the temperature of a coil must be the resistance method, but temperature measurements by either the thermocouple or resistance method may be conducted. The thermocouple method must not be conducted for a temperature measurement at any point at which supplementary insulation is employed.

11) As it is usually necessary to de-energize the winding before measuring resistance, the value of resistance at shutdown may be determined by taking several resistance measurements at short intervals, beginning as quickly as possible after initiating shutdown. A curve of the resistance values and the time must be plotted and extrapolated to give the value of resistance at shutdown.

12) Upon completion of the temperature test, the sample must comply with the requirements of the dielectric strength test (AC or DC *insulation* test) as specified in 5.2.3.4.

Table T.26 – Ampacities of insulated conductors

Wire size		**60 °C**		**75 °C**	
AWG	mm^2	Copper	Aluminum	Copper	Aluminum
14	2,1	15	—	15	—
12	3,3	20	15	20	15
10	5,3	30	25	30	25
8	8,4	40	30	50	40
6	13,3	55	40	65	50
4	21,2	70	55	85	65
3	26,7	85	65	100	75
2	33,6	95	75	115	90
1	42,4	110	85	130	100
0	53,5	—	—	150	120
00	67,4	—	—	175	135
000	85,0	—	—	200	155
0000	107,2	—	—	230	180
kcmil					
250	127	—	—	255	205
300	152	—	—	285	230
350	177	—	—	310	250
400	203	—	—	335	270
500	253	—	—	380	310
600	304	—	—	420	340
700	355	—	—	460	375
750	380	—	—	475	385
800	405	—	—	490	395
900	456	—	—	520	425
1 000	506	—	—	545	445
1 250	633	—	—	590	485
1 500	760	—	—	625	520
1 750	887	—	—	650	545
2 000	1 013	—	—	665	560

For multiple conductors of the same size (1/0 AWG or larger) at a terminal, the ampacity is equal to the value in this table for that conductor multiplied by the number of conductors that the terminal will accommodate.

These values of ampacity apply only if not more than three conductors will be field installed in the conduit. If four or more conductors, other than a neutral that carries the unbalanced current, will be installed in a conduit, the derating factors specified in Table T.9 must be applied.

Table T.27 – Size of copper busbar connections for temperature test

Product rating A	**Busbars per terminal**	**Width of busbar** mm
450 to 600	1	51
601 to 1000	1	76
1 001 to 1 200	1	102
1 201 to 1 600	2	76
1 601 to 2 000	2	102
2 001 to 2 500	2	127
2 001 to 2 500	4	64
2 501 to 3 000	3	127
2 501 to 3 000	4	102
See T.5.2.3.10 6).		

T.5.2.3.11 *Protective equipotential bonding* test (*type test*, *routine test*)

Modification to 5.2.3.11:

Tests are not applicable and replaced by tests specified in CSA C22.2 No. 0.4.

T.5.2.4 *Abnormal operation* and simulated faults tests

T.5.2.4.1 General

Modification to 5.2.4.1:

5.2.4.1 a), b) and c) are not applicable.

Additional subclause to 5.2.4.1:

T.5.2.4.1.200 *Abnormal operation* and simulated faults tests

1) For the short-circuit test, a 30 A non-time-delay fuse must be connected between the *enclosure* and ground.
2) *open type BDM/CDM* may also be tested in an outer *enclosure* that meets the size and ventilation requirements specified in the *BDM/CDM/PDS* installation instructions.
3) For higher fault current tests, two alternatives to this are the following:
   a) for safety reasons, a current clamp instead of a 30 amp fuse may be used; or
   b) as an alternative to the 30 amp fuse to ground, the test set-up may employ a wire connected from the *enclosure* to ground. This wire must be sized per Table T.2, or sized in accordance with the input wiring size requirements of T.5.2.4.1.200 5), whichever is smaller.
4) The branch-circuit short-circuit protection requirements for conducting the high fault current short-circuit test for *low-voltage BDM*/*CDM*/*PDS* must be as follows:
   a) Except as permitted by T.5.2.4.1.200 4) b), fuses specified for branch-circuit protection for *BDM/CDM/PDS* rated over 10 000 A must be limited to high-interrupting capacity, current-limiting types (e.g., HRCI-R, -J, -T and –MISC, or HRCII-C and –MISC).
   b) For *BDM*/*CDM*/*PDS* rated 50 hp or less and tested at 10 000 A, cartridge-enclosed fuses in compliance with the CAN/CSA-C22.2 No. 248 series of standards may be specified for motor branch-circuit protection.

c) A test limiter complying with CAN/CSA-C22.2 No. 248.16 for the specific class of fuse may be used in place of the fuses specified in T.5.2.4.1.200 4) a) and b).

5) Input/output wiring

The wire size of the input and output wiring must be in accordance with Table T.26. The ampacity of the wiring must be based on the marked wire temperature rating (either 60 °C or 75 °C) and each of the following.

a) The main input power wiring must be sized for 125 % of the rated *BDM/CDM/PDS* input current.

b) For *low-voltage* motors, the *BDM/CDM/PDS* output power wiring must be sized for 125 % of the rated full-load current, or must be sized for 125 % of the output full-load motor current specified in Table T.12, based on the rated horsepower rating.

c) For high-voltage motors, the *BDM/CDM/PDS* output power wiring must be sized for 125 % of the rated full-load current, as specified by the motor manufacturer.

6) Input and output wiring may be routed through 250 mm to 305 mm lengths of conduit installed on the *enclosure*. If conduit is not used, then the wire must be routed through a bushing appropriate for the size of the conductors.

Table T.28 – Short-circuit test values

Device rating (600 V max.), hp	**Full-load current**, A, at 601 V to 1500 V	**Test current**, A[a]	**Power factor**[b]
0 to 1-1/2[c]	—	1 000	0,70 to 0,80
0 to 50	0 to 50	5 000	0,70 to 0,80
51 to 200	51 to 200	10 000	0,70 to 0,80
201 to 400	201 to 400	18 000	0,25 to 0,30
401 to 600	401 to 600	30 000	0,20 or less
601 to 900	601 to 850	42 000	0,20 or less
901 to 1 600	851 to 1 500	85 000	0,20 or less

[a] Symmetrical RMS amperes.

[b] For DC circuits, the L/R time constant must be 3 μs for test currents of 10 000 A and less and 8 μs for test currents above 10 000 A.

[c] 300 V or less, one-phase.

For current-rated controllers, use the equivalent horsepower rating derived from Table T.12 or Table T.13, as applicable.

For BDM/CDM/PDS rated greater than 750 volts, short-circuit rating must be as determined by the manufacturer but not less than 10 000 amps.

T.5.2.4.2 Supply voltage, current and frequency

Replacement of Table 36 with Table T.28.

Additional subclause to 5.2.4.2:

T.5.2.4.2.200 *BDM/CDM/PDS* rated for high fault current

1) A *BDM/CDM/PDS* rated for high fault current (higher than Table T.28) can be tested as per Table T.28 only, if following conditions are met:

a) the *BDM/CDM/PDS* series uses solid state short-circuit protection circuitry for compliance with the standard fault current short-circuit test;

b) the protection circuitry serves to shut off a transistor based semiconductor device prior to significant increase in current; and

c) the short-circuit output current source is an energy storage device, such as a capacitor bank.

2) The circuit capability for these tests must be verified in accordance with the calibration of short-circuit test circuit, T.5.2.4.2.200 3).

3) Short-circuit calibration of test circuits

a) General

i) The available current capacity of the circuit must not be less than the value required for the short-circuit rating of the *BDM/CDM/PDS*. With the supply terminals short-circuited, the capacity must be determined at the minimum point on the current wave closest to, but not less than, one-half cycle after circuit closure based on a test frequency timing wave. The frequency of the test circuits must be 60 Hz ± 12 Hz.

ii) For an AC circuit intended to deliver 10 000 A or less, the current and power factor must be determined in accordance T.5.2.4.2.200 3) b). For circuits designed to deliver more than 10 000 A, the current and power factor must be determined in accordance with T.5.2.4.2.200 3) c) i) to 3) c) viii). Instrumentation used to measure test circuits of over 10 000 A must meet the requirements specified in T.5.2.4.2.200 3) c) ix) to 3) c) xix).

b) Measurement of currents 10 000 A and less. Measurement must be conducted as follows.

i) The current in a three-phase test circuit must be checked by averaging the RMS values of the first complete cycle of current in each of the three phases.

ii) The current in a single-phase test circuit must be checked by determining the RMS value of the first complete cycle (see Figure T.8) when the circuit is closed to produce an essentially symmetrical current waveform.

iii) The AC component must not be added to the value obtained when measured as shown in Figure T.8.

iv) In order to obtain the desired symmetrical waveform of a single-phase test circuit, controlled closing is recommended, although random closing methods may be used.

v) The power factor must be determined by referring the open-circuit voltage wave to the two adjacent zero points at the end half of the first complete current cycle by transposition through a suitable timing wave.

vi) The power factor must be computed as an average of the values obtained by using these two current zero points, and the voltage to neutral must be used in the case of a three-phase circuit.

c) Measurement of currents over 10 000 A

i) The RMS symmetrical current must be determined with the supply terminals short-circuited by measuring the AC component of the wave at an instant half-cycle (on the basis of the test frequency timing wave) after the initiation of the short-circuit. The current must be calculated in accordance with Figure 7 of IEEE C37.09-1999.

ii) For a three-phase test circuit, the RMS symmetrical current must be the average of the currents in the three phases. The RMS symmetrical current in any one phase must be not less than 90 % of the required test current.

iii) The test circuit and its transients must be such that

1) three cycles (1/20 s) after initiation of the short-circuit, the symmetrical alternating component of current will be not less than 90 % of the symmetrical alternating component of current at the end of the first half-cycle; or

2) the symmetrical alternating component of current at the time at which the *overcurrent* protective device will interrupt the test circuit must be at least 100 % of the rating for which the controller is being tested. In three-phase circuits, the symmetrical alternating component of current of all three phases must be averaged.

iv) The power factor must be determined at an instant one half-cycle (on the basis of the test frequency timing wave) after the short-circuit occurs. The total asymmetrical RMS amperes must be measured in accordance with T.5.2.4.2.200 3) c) i) and the ratio M_A or M_M calculated as follows:

For three-phase:

$$M_\mathrm{A} = \frac{X}{Y}$$

where

M_A is the average three phase ratio;

X is the average three phase asymmetrical RMS amperes;

Y is the average three phase symmetrical RMS amperes.

For single phase:

$$M_\mathrm{M} = \frac{X_\mathrm{s}}{Y_\mathrm{s}}$$

where

M_M is the single phase ratio;

X_s is the asymmetrical RMS amperes;

Y_s is the symmetrical RMS amperes.

Using M_A or M_M, the power factor must be determined from Table T.29.

v) The power factor of a three-phase circuit may be calculated using controlled closing so that, upon subsequent closings, a different phase will have maximum asymmetrical conditions. Each phase will then have the power factor determined using the method specified for single-phase circuits in T.5.2.4.2.200 3) c) iv). The power factor of the three-phase circuit must be considered to be the average of the power factors determined for each of the phases.

vi) The recovery voltage must be at least equal to the rated voltage of the *BDM/CDM/PDS*. The peak value of the recovery voltage within the first full half-cycle after clearing and for the next five successive peaks must be at least equal to 1,4 times the RMS value of the rated voltage of the controller. Each of the peaks must be displaced by not more than ±10° elec from the peak values of the open-circuit recovery voltage (i.e. the displacement of the peak from its normal position on a sinusoidal wave). The average of the instantaneous values of recovery voltage of each of the first six half-cycles measured at the 45 point and 135 point on the wave must be not less than 85 % of the RMS value of the rated voltage of the BDM/CDM/PDS. The instantaneous value of recovery voltage measured at the 45 point and 135 point of each of the first six half-cycles must not be less than 75 % of the RMS value of the rated voltage of the BDM/CDM/PDS.

vii) If, in a circuit that employs secondary closing, there is no attenuation or phase displacement of the first full cycle of the recovery voltage wave when compared with the open-circuit secondary voltage wave before current flow, the detailed measurement of recovery voltage characteristics specified in T.5.2.4.2.200 3) c) vi) must not be required.

viii) The shunting resistance used with an air core reactor having negligible resistance must be calculated from the following formula:

$$R = 167\frac{E}{I}$$

where

R is the shunting resistance;

E is the voltage across the air core reactor;

I is the current flowing, as determined by oscillographic measurement during the short-circuit calibration or, by proportion, from meter measurements at some lower current.

ix) For an AC circuit, the current and power factor must be determined in accordance with T.5.2.4.2.200 3) c) i) to 3) c) vii). Instrumentation used to measure test circuits must meet the requirements of T.5.2.4.2.200 3) c) x) to 3) c) xix).

x) The galvanometers in a magnetic oscillograph employed for recording voltage and current during circuit calibration, and while testing, must be of a type having a flat (±5 %) frequency response from 50 Hz to 1 200 Hz.

For fast-acting fuses, current limiters, or motor short-circuit protectors, a galvanometer with a flat frequency response from 50 Hz to 9 000 Hz or an oscilloscope may be used to obtain accurate values of I_{p} and I^2t.

xi) Galvanometers must be calibrated as specified in T.5.2.4.2.200 3) c) xii) to 3) c) xv).

xii) When a shunt is used to determine the circuit characteristics, the following must apply.

1) A DC calibrating voltage must normally be used.
2) The voltage applied to the oscillograph galvanometer circuit must result in a deflection of the galvanometer approximately equivalent to that which is expected when the same galvanometer circuit is connected to the shunt and the nominal short-circuit current is flowing.
3) The voltage must be applied so as to cause the galvanometer to deflect in both directions.
4) Additional calibrations must be made using approximately 50 % and 150 % of the voltage used to obtain the deflection, except that if the anticipated maximum deflection is less than 150 %, such as in a symmetrically closed single-phase circuit, any other suitable calibration point must be chosen.
5) The sensitivity of the galvanometer circuit in volts per inch must be determined from the deflection measured in each case, and the results of the six trials averaged.
6) The peak amperes per inch must be obtained by dividing the sensitivity by the resistance of the shunt.
7) The multiplying factor must be used for the determination of the RMS symmetrical current as specified in T.5.2.4.2.200 3) c) i).

xiii) When a current transformer is used to determine the circuit characteristics, the following must apply.

1) An AC current must be used to calibrate the galvanometer circuit.
2) The value of current applied to the galvanometer circuit must result in a deflection of the galvanometer approximately equivalent to that which is expected when the same galvanometer circuit is connected to the secondary of the current transformer and the nominal short-circuit current is flowing in the primary.
3) Additional calibrations must be made at approximately 50 % and 150 % of the current used to obtain the deflection, except that if the anticipated maximum deflection is less than 150 %, such as in a symmetrically closed single-phase circuit, any other suitable calibration point must be chosen.
4) The sensitivity of the galvanometer circuit in RMS amperes per inch must be determined in each case and the results averaged.
5) The average sensitivity must be multiplied by the current transformer ratio and by 1,4 to obtain peak amperes per inch.

6) This constant must be used for determining the RMS symmetrical current as specified in T.5.2.4.2.200 3) c) i).

xiv) All the galvanometer elements employed must line-up properly in the oscillograph, or the displacement differences must be noted and used as needed.

xv) A 60 Hz sine wave voltage may be used for calibrating the galvanometer circuit, using the general method specified in T.5.2.4.2.200 3) c) xi). The resulting factor must be multiplied by 1,4.

xvi) The sensitivity of the galvanometers or the recording speed must be sufficient to provide a record from which values of voltage, current, and power factor can be measured accurately. The recording speed must be not less than 1 500 mm/s. Higher speeds are recommended.

xvii) With the test circuit adjusted to provide the specified values of voltage and current, and with a non-inductive (coaxial) shunt that has been found suitable for use as a reference connected into the circuit, the tests specified in T.5.2.4.2.200 3) c) xviii) and xix) must be conducted to verify the accuracy of the manufacturer's instrumentation.

xviii) With the secondary open-circuited, the transformer must be energized and the voltage at the test terminals observed to confirm whether rectification occurs, making the circuit unacceptable for test purposes because the voltage and current will not be sinusoidal. Six random closings must be made to demonstrate that residual flux in the transformer core will not cause rectification. If testing is done by closing the secondary circuit, this check may be omitted, provided that testing does not commence before the transformer has been energized for approximately 2 s, or longer if an investigation of the test BDM/CDM/PDS shows that a longer time is necessary.

xix) With the circuit short-circuited by connecting the test terminals together by means of a copper bar, a single-phase circuit must be closed as nearly as possible at the angle that will produce a current wave with maximum offset.

xx) The short-circuit current and voltage must be recorded. The primary voltage must be recorded if primary closing is used. The current measured by the reference shunt must be within 5 % of that measured using the manufacturer's instrumentation, and there must be no measurable variation in phase relationship between the traces of the same current. Controlled closing must not be required for polyphase circuits.

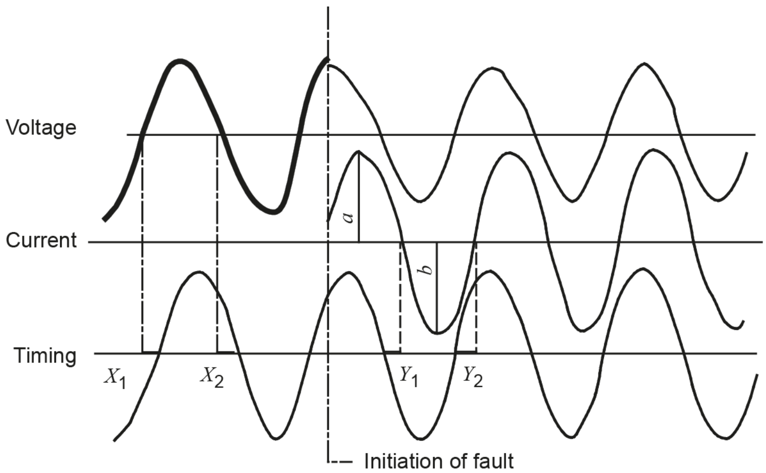
xxi) When the verification of the accuracy of the manufacturer's instrumentation is completed, the reference coaxial shunt must be removed from the circuit. The reference coaxial shunt must not be used during the final calibration of the test circuit or during the testing of the controllers.

Table T.29 – Short-circuit power factor

Short-circuit power factor %	Ratio M_M [a]	Ratio M_A [a]	Short-circuit power factor %	Ratio M_M [a]	Ratio M_A [a]
0	1,732	1,394	30	1,130	1,066
1	1,696	1,374	31	1,121	1,062
2	1,665	1,355	32	1,113	1,057
3	1,630	1,336	33	1,105	1,053
4	1,598	1,318	34	1,098	1,049
5	1,568	1,301	35	1,091	1,046
6	1,540	1,285	36	1,084	1,043
7	1,511	1,270	37	1,078	1,039
8	1,485	1,256	38	1,073	1,036
9	1,460	1,241	39	1,068	1,033

Short-circuit power factor %	Ratio M_M[a]	Ratio M_A[a]	Short-circuit power factor %	Ratio M_M[a]	Ratio M_A[a]
10	1,436	1,229	40	1,062	1,031
11	1,413	1,216	41	1,057	1,028
12	1,391	1,204	42	1,053	1,026
13	1,372	1,193	43	1,049	1,024
14	1,350	1,182	44	1,045	1,022
15	1,330	1,171	45	1,041	1,020
16	1,312	1,161	46	1,038	1,019
17	1,294	1,152	47	1,034	1,017
18	1,277	1,143	48	1,031	1,016
19	1,262	1,135	49	1,029	1,014
20	1,247	1,127	50	1,026	1,013
21	1,232	1,119	55	1,015	1,008
22	1,218	1,112	60	1,009	1,004
23	1,205	1,105	65	1,004	1,002
24	1,192	1,099	70	1,002	1,001

[a] See T.5.2.4.2.200 3) c) iv).



Current = $\frac{a + b}{2}$ × rms calibration of instrument element

Power factor = $\frac{\text{Cosine }[(Y_1 + X_1) \times 180] + \text{Cosine }[(Y_2 + X_2) \times 180]}{2}$

where

X and Y values = fractions of the 1/2 cycle distance in which they occur

IEC

Figure T.8 – Determination of current and power factor for circuits of 10 000 A and less

T.5.2.4.3 Acceptance criteria

Modification to 5.2.4.3:

1) The *door* or *cover* must not be blown open, and it must be possible to open the *door* or *cover*. Deformation of the *enclosure* must be considered acceptable.

2) During and after the test, accessible *extra-low voltage* (*ELV*) circuits must not exceed their voltage rating (30 V AC/42 V DC).
3) The 30 A non-time-delay ground fuse, when used, must not have opened.
4) When the current clamp is used, the maximum measured current must not exceed 30 amps RMS.
5) The shorting or opening of PN junctions in semiconductor devices, or cracking or opening of the semiconductor case or package, must be considered acceptable.

T.5.2.4.4 ***Protective equipotential bonding*** **short-circuit withstand test (*type test*)**

T.5.2.4.5 Output short-circuit test (*type test*)

T.5.2.4.5.1 Load conditions

T.5.2.4.5.2 Short-circuit test between phase terminals of output power *port* (*type test*)

T.5.2.4.5.3 Short-circuit test between phase terminals of output power *ports* and earth (*type test*)

Modification to 5.2.4.5.3:

The routing test is not applicable.

Additional subclause to 5.2.4.5:

T.5.2.4.5.200 General

1) Unless the *BDM/CDM/PDS* is marked to restrict the protective device to fuses or inverse-time circuit breakers, it must be tested with both fuses and inverse-time circuit breakers.
2) Semiconductor fuses may be included as supplementary protection only when provided integral to the *BDM/CDM/PDS*.
3) Short-circuit testing of a single *BDM/CDM/PDS* model must be considered representative of other *BDM/CDM/PDS* in the same series when the following conditions are met:
   a) the *BDM/CDM/PDS* series uses internal solid state short-circuit protection;
   b) the same protection is used throughout the series;
   c) the protection circuitry serves to shut off the *BDM/CDM/PDS* prior to significant increase in current; and
   d) the short-circuit output current source is an energy storage device, such as a capacitor bank.
4) Criteria for selecting test samples, must include the following:
   a) comparison of the fuse or circuit breaker let-through ratings with the semiconductor device ratings for each model within the series.

      NOTE The specific ratings to evaluate are the maximum I^2t and maximum I_p values.

   b) bracing of *components* and subassemblies such as bus bars;
   c) thermal heat transfer capability; and
   d) variances in the short-circuit ratings of the individual models.

T.5.2.4.5.201 Protective devices

1) Protective devices as described in T.5.2.4.5.201 2) to 6) must be provided for the short-circuit test.

2) Unless *BDM/CDM/PDS* is marked to specify that branch-circuit short-circuit protection must be provided by fuses only (in which case testing with circuit breakers is not required), they must always be tested with fuses and circuit breakers. Semiconductor fuses may be included as supplementary protection only when provided integral to the *BDM/CDM/PDS*.

3) The *overcurrent* protective device for this test must be appropriate for branch-circuit protection in accordance with the Canadian Electrical Code, Part I, and must be in accordance with the markings specified in T.6.3.9.6.201 and T.6.3.9.6.202, as applicable. When the *BDM/CDM/PDS* is marked with a high fault current rating, the *overcurrent* protective device must also comply with T.5.2.4.5.201 4).

4) The fuse used for the short-circuit tests specified in 5.2.4.5 must be as specified by the manufacturer and must be one of the following fuse.

   a) Non-time-delay fuse not exceeding 600 A rated 4 times the maximum full-load motor-running current rating. If the calculated value of the fuse is between two standard ratings as specified in T.5.2.4.5.201 7), a fuse of the nearest standard rating, but not more than 4 times the full-load motor-running current rating, must be used. If the calculated value of the fuse is less than 1 A, a fuse rated 1 A must be used. No marking of the fuse size is required on the product.

   b) Non-time-delay fuse not exceeding 600 A and smaller than the size specified in T.5.2.4.5.201 4) a) but greater than 225 % of the full-load motor-running current rating if the product is marked to indicate this limit of protection.

   c) Time-delay fuse not exceeding 600 A rated 225 % or less of the full-load motor-running current rating if the product is marked to indicate the level of protection and that the branch-circuit protective device may, if necessary, be of the time-delay type.

   d) Non-time-delay fuse, 601 A to 6 000 A, rated 3 times the maximum full-load motor-running current rating. If the calculated value of the fuse is between two standard ratings as specified in T.5.2.4.5.201 7), a fuse of the nearest standard rating, but not more than 3 times the full-load motor-running current rating, must be used. No marking of fuse size is required on the product. For the purposes of this requirement, a fuse rated 601 A is considered to be a standard rated fuse.

   e) Non-time-delay fuse smaller than the size specified in T.5.2.4.5.201 4) d) if the product is marked to indicate this limit of protection.

5) Except as required by T.5.2.4.5.201 4) b) and e), no marking of the fuse type on the product is required when the short-circuit tests specified in T.5.2.4.5.201 1) are performed at 5 kA and 10 kA levels using standard non-time-delay, non-renewable class H type cartridge fuses.

6) An inverse-time circuit breaker used for the short-circuit test specified in T.5.2.4.5.201 1) and 2) must be that specified by the manufacturer and

   a) be rated 4 times the maximum full-load motor-current rating for full-load currents of 100 A or less, or 3 times the maximum full-load motor-current rating for full-load currents greater than 100 A. If the calculated value of the circuit breaker is between two standard ratings as specified in T.5.2.4.5.201 7), a circuit breaker of the nearest standard rating, not more than 4 times or not more than 3 times the full-load motor-running current rating, must be used. If the calculated value of the circuit breaker is less than 15 A, a circuit breaker rated 15 A must be used (no marking of the circuit breaker rating is required on the product); or

   b) have a rating less than that specified in T.5.2.4.5.201 2)a). If less than 250 %, the product must be marked to indicate the limit of protection.

7) Standard ampere ratings for fuses are 1, 3, 6, and 10. For fuses larger than 10 A and inverse-time circuit breakers, standard ampere ratings are 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 700, 800, 1 000, 1 200, 1 600, 2 000, 2 500, 3 000, 4 000, 5 000, and 6 000.

T.5.2.4.6 *Electronic motor overload protection* test (*type test*)

T.5.2.4.7 Circuit functionality evaluation test (*type test*, *routine test, sample test*)

T.5.2.4.8 Current limiting test (*type test*)

T.5.2.4.9 Output overload test (*type test*)

Additional subclause to 5.2.4.9:

T.5.2.4.9.200 Contact overload test (*type test*)

1) Except where indicated in T.5.2.4.9.200 2), a contactor must be rated and approved for the maximum current, power, and voltage that the particular circuit is capable of producing and must be capable of making and breaking the load current of the circuit.
2) A contactor not rated for the maximum current and having the coil circuit interlocked or sequenced in such a way that, under normal operating conditions, the contactor does not make or break load current, must be tested at the maximum overload current, power, and voltage that the particular circuit is capable of producing. Five operations must be conducted. The cycle time for AC circuits must be a minimum four electrical cycles on and a maximum 240 s off. The electrical cycles must be based on the minimum operating frequency of the circuit involved. For DC circuits, the on time must be at least the larger of a) or b), as follows:
   a) the time it takes for the current to reach the maximum possible overload value; or
   b) four electrical cycles of the AC mains that the DC source is derived from (if applicable), where the electrical cycles are based on the minimum operating frequency of the AC mains.

For DC circuits, the off time must be a maximum 240 s.

T.5.2.4.10 Breakdown of *component* test (*type test*)

T.5.2.4.11 PWB short-circuit test (*type test*)

Addition to 5.2.4.11:

1) A 3 A Class CC, non-time-delay fuse must be connected between the supply circuit pole least likely to arc to ground and the outer *enclosure* (if any) and grounded or exposed dead metal parts.
2) Temperatures must be monitored on *components* that are most likely to overheat during the test
3) As a result of the tests, the 3 A class CC non-time-delay fuse connected in the *BDM/CDM/PDS* grounding circuit must not open.
4) If a wire or a printed wiring board trace opens, the gap must be electrically shorted and the test continued. This requirement must apply to each occurrence.
5) If the opening of a *component* other than a supplementary *overcurrent* device interrupts the circuit, the test must be repeated twice, using new *components* as necessary.

T.5.2.5 Material tests

T.5.2.5.1 General

T.5.2.5.2 High current arcing ignition test (*type test*)

Replacement of 5.2.5.2 with tests specified in CSA C22.2 No. 0.17.

T.5.2.5.3 Glow-wire test (*type test*)

Replacement of 5.2.5.3 with tests specified in CSA C22.2 No. 0.17.

T.5.2.5.4 Hot wire ignition test (*type test* – alternative to glow-wire test)

Addition to 5.2.5.4:

Polymeric *enclosure* must be tested, as required, in accordance with the hot-wire ignition test specified in CSA C22.2 No. 0.17, and the *enclosure* material must not ignite within 15 s when subjected to this test.

T.5.2.5.5 Flammability test (*type test*)

Addition to 5.2.5.5:

1) *enclosure*s must be tested in accordance with flame test A (15 s) in Clause D.1 of CSA C22.2 No. 0.17, or
2) *enclosure*s must be tested in accordance with flame test B (5 s) in Clause D.2 of CSA C22.2 No. 0.17 and comply with T.5.2.5.4.

T.5.2.5.6 Cemented joints test (*type test*)

T.5.2.5.7 Ultra-violet (UV) resistance test (*type test*)

5.2.5.7 is not applicable; see requirements in 4.12.9.

T.5.2.6 Environmental tests (*type tests*)

T.5.2.7 Hydrostatic pressure test (*type test, routine test*)

T.5.2.8 Electromagnetic fields (EMF) test (*type test*)

5.2.8 is not applicable.

T.6 Information and marking requirements

T.6.1 General

Additional subclause to 6.1:

T.6.1.200 Translation

In Canada, the translations shown in Table T.30 must be used.

Table T.30 – Translation of markings

Clause reference	English marking	French marking
T.6.2.1.200 4)	CAUTION: BONDING BETWEEN CONDUITS MUST BE PROVIDED	ATTENTION: LES CONDUITS DOIVENT ÊTRE RELIÉS PAR LA MASSE
6.5.5	WARNING: MORE THAN ONE LIVE CIRCUIT. SEE DIAGRAM	AVERTISSEMENT: PLUS D'UN CIRCUIT EST SOUS TENSION. VOIR SCHÉMA
T.6.3.5.200	OR EQUIVALENT	OU L'ÉQUIVALENT
T.6.3.5.200	WARNING: WHEN MOUNTING ON OR OVER A COMBUSTIBLE SURFACE, A FLOOR PLATE OF AT LEAST 1.43 mm GALVANIZED OR 1.6 mm UNCOATED STEEL EXTENDED AT LEAST 150 mm BEYOND THE EQUIPMENT ON ALL SIDES MUST BE INSTALLED	AVERTISSEMENT : SI L'APPAREIL EST INSTALLÉ SUR UN SOL OU PRÈS D'UNE SURFACE COMBUSTIBLE, UNE PLAQUE DE SOL D'AU MOINS 1,43 mm EN MÉTAL GALVANISÉ OU 1,6 mm EN ACIER NON PLAQUÉ, QUI DÉPASSE D'AU MOINS 150 mm LE POURTOUR DE L'APPAREIL, DOIT ÊTRE INSTALLÉE SOUS CE DERNIER
T.6.2.1.200 Clause 3)	TWIST WIRES TOGETHER BEFORE INSERTING IN TERMINAL	RETORDRE LES FILS ENSEMBLE AVANT DE LES INSÉRER DANS LA BORNE

Clause reference	English marking	French marking
T.6.2.1.200 Clause 3)	COPPER WIRES MUST NOT BE MIXED WITH ALUMINUM WIRES IN THE SAME TERMINAL HOLE	NE PAS ENFILER DES CONDUCTEURS EN CUIVRE ET DES CONDUCTEURS EN ALUMINIUM ENSEMBLE DANS UN MÊME TROU DE BORNE
T.6.3.9.6.200	SUITABLE FOR USE ON A CIRCUIT CAPABLE OF DELIVERING NOT MORE THAN ___ RMS SYMMETRICAL AMPERES, ___ V MAXIMUM	CONVIENT AUX CIRCUITS NON SUSCEPTIBLES DE DÉLIVRER PLUS DE ___ AMPÈRES SYMÉTRIQUES EFF., MAXIMUM ___ V
T.6.3.9.6.201	WHEN PROTECTED BY ___ (B) ___ WITH A MAXIMUM RATING OF ___ (C) ___	AVEC UNE PROTECTION PAR ___ (B) ___ DE CALIBRE NOMINAL MAXIMAL DE ___ (C) ___
T.6.3.9.6.201	"fuses" or "a circuit breaker"	«des fusibles» ou «un disjoncteur»
T.6.3.9.6.201	WHEN PROTECTED BY ___ CLASS FUSES	AVEC PROTECTION PAR DES FUSIBLES DE CALIBRE ___
T.6.3.9.6.201	WHEN PROTECTED BY A CIRCUIT BREAKER HAVING AN INTERRUPTING RATING NOT LESS THAN ___ RMS SYMMETRICAL AMPERES, ___ V MAXIMUM	AVEC PROTECTION PAR UN DISJONCTEUR À POUVOIR DE COUPURE NOMINAL D'AU MOINS ___ AMPÈRES SYMÉTRIQUES EFF., MAXIMUM ___ V
T.6.3.9.6.202	ATTENTION THE OPENING OF THE BRANCH-CIRCUIT PROTECTIVE DEVICE MAY BE AN INDICATION THAT A FAULT HAS BEEN INTERRUPTED. TO REDUCE THE RISK OF FIRE OR ELECTRIC SHOCK, CURRENT-CARRYING PARTS AND OTHER COMPONENTS OF THE CONTROLLER SHOULD BE EXAMINED AND REPLACED IF DAMAGED. IF BURNOUT OF THE CURRENT ELEMENT OF AN OVERLOAD RELAY OCCURS, THE COMPLETE OVERLOAD RELAY MUST BE REPLACED	ATTENTION LE DÉCLENCHEMENT DU DISPOSITIF DE PROTECTION DU CIRCUIT DE DÉRIVATION PEUT ÊTRE DÛ À UNE COUPURE QUI RÉSULTE D'UN COURANT DE DÉFAUT. POUR LIMITER LE RISQUE D'INCENDIE OU DE CHOC ÉLECTRIQUE, EXAMINER LES PIÈCES PORTEUSES DE COURANT ET LES AUTRES ÉLÉMENTS DU CONTRÔLEUR ET LES REMPLACER S'ILS SONT ENDOMMAGÉS. EN CAS DE GRILLAGE DE L'ÉLÉMENT TRAVERSÉ PAR LE COURANT DANS UN RELAIS DE SURCHARGE, LE RELAIS TOUT ENTIER DOIT ÊTRE REMPLACÉ
T.6.3.9.6.203	INTEGRAL SOLID STATE SHORT-CIRCUIT PROTECTION DOES NOT PROVIDE BRANCH CIRCUIT PROTECTION. BRANCH CIRCUIT PROTECTION MUST BE PROVIDED IN ACCORDANCE WITH THE CANADIAN ELECTRICAL CODE, PART I	LA PROTECTION INTÉGRÉE CONTRE LES COURTS-CIRCUITS N'ASSURE PAS LA PROTECTION DE LA DÉRIVATION. LA PROTECTION DE LA DÉRIVATION DOIT ÊTRE EXÉCUTÉE CONFORMÉMENT AU CODE CANADIEN DE L'ÉLECTRICITÉ, PREMIÈRE PARTIE.
T.6.4.202 1)	DANGER HIGH VOLTAGE KEEP OUT OR DANGER: ____ V	DANGER HAUTE TENSION ENTRÉE INTERDITE OU DANGER : ____ V
T.6.4.202 5)	WARNING: FUSES MAY BE ENERGIZED	AVERTISSEMENT : LES FUSIBLES PEUVENT ÊTRE SOUS TENSION
T.6.5.2	WARNING : RISK OF ELECTRIC SHOCK. DANGEROUS VOLTAGE MAY EXIST FOR 5 MINUTES AFTER REMOVING POWER	AVERTISSEMENT : RISQUE DU CHOC ÉLECTRIQUE. UNE TENSION DANGEREUSE PEUT ÊTRE PRÉSENTÉE JUSQU'À 5 MINUTES APRÈS AVOIR COUPÉ L'ALIMENTATION
T.6.3.9.1.1.200	WARNING : RISK OF ELECTRIC SHOCK — HEAT SINK ARE LIVE — DISCONNECT POWER SUPPLY BEFORE SERVICING	AVERTISSEMENT : RISQUE DE CHOC ÉLECTRIQUE – LES DISSIPATEURS THERMIQUES SONT SOUS TENSION – COUPEZ L`ALIMENTATION AVANT D`EFFECTUER LA RÉPARATION

Clause reference	English marking	French marking
T.6.4.201	TRANSIENT SURGE SUPPRESSION SHALL BE INSTALLED ON THE LINE SIDE OF THIS EQUIPMENT AND SHALL BE RATED _____ V (PHASE TO GROUND), SUITABLE FOR OVERVOLTAGE CATEGORY _____, AND SHALL PROVIDE PROTECTION FOR A RATED IMPULSE WITHSTAND VOLTAGE PEAK OF _____ KV	TRANSITOIRES DOIT SE TROUVER DU CÔTÉ SECTEUR DE CET APPAREILLAGE ET CONVENIR À _____ V (PHASE-TERRE), APPARTENIR À LA CATÉGORIE DE SURTENSION _____, ET RÉSISTER À UNE TENSION DE CHOC DE CRÊTE NOMINALE DE _____ KV

T.6.2 Information for selection

T.6.2.1 General

Additional subclause to 6.2.1:

T.6.2.1.200 Control of motors exceeding 500 hp

1) *BDM/CDM/PDS* intended to control a motor exceeding 500 hp must, in addition to the horsepower ratings, include the maximum full-load current for each rating.
2) *BDM/CDM/PDS* supplied from more than one supply (power) circuit must be provided with the required marking for each supply circuit.

   NOTE The term "supply circuit" does not include interlocking or *control circuit*s rated 15 A or less.

3) Where more than one bonding conductor No. 6 AWG or smaller must be terminated in a single- or multiple-conductor terminal that will accept a range of conductor sizes, the marking TWIST WIRES TOGETHER BEFORE INSERTING IN TERMINAL must appear adjacent to the bonding terminal. If the terminal is suitable for both copper and aluminum conductors, the additional marking COPPER WIRES MUST NOT BE MIXED WITH ALUMINUM WIRES IN THE SAME TERMINAL HOLE or its equivalent must also appear adjacent to the bonding terminal.
4) Polymeric *enclosure* utilizing metallic conduits must be provided with the following or equivalent wording: CAUTION: BONDING BETWEEN CONDUITS MUST BE PROVIDED.

T.6.2.2 Instructions and markings pertaining to *accessories*

Additional subclause to 6.2.2:

T.6.2.2.200 Field kits and *accessories*

1) Identification of the kits that can be installed in the *BDM/CDM/PDS* must be marked on the *BDM/CDM/PD*, supplied separately, or included in the manufacturer's catalogues.
2) The kit, or its smallest unit package, must be marked with its catalogue number (or equivalent) and the name or trademark of the manufacturer.
3) The connector kit, or its package, must be marked with its identification and the name or trademark of the manufacturer. Information detailing the range of conductor sizes that the connector is intended to accommodate must be marked on, or included as a separate sheet with the kit, its container or package, the main device, or its *enclosure*.
4) Unless proper installation of a kit is clearly evident, assembly instructions must be provided as part of the kit or as part of the industrial control equipment and must include
   a) clear identification of the individual parts, *components*, or sub-assemblies,
   b) schematic or wiring diagrams, if applicable, and
   c) explicit assembly information that describes all aspects of assembly.
5) Parts and *component*s of a kit must be identified, if required, in a way that ensures proper matching with the schematic or wiring diagram.

T.6.3 Information for installation and commissioning

T.6.3.1 General

Additional subclause to 6.3.1:

T.6.3.1.200 Manual provided in hard copy or electronic format

The installation manual may be provided in hard copy or electronic format and should be retained with this device at all times. The installation and maintenance manuals must include details of all necessary connections, together with a suggested interconnection diagram.

T.6.3.2 Mechanical considerations

T.6.3.3 Environment

Addition to 6.3.3:

When requested by T.4.4.7.1.3 and T.4.4.7.1.4, the pollution degree and overvoltage category must be marked at location 1 according to Table 48.

T.6.3.4 Handling and mounting

T.6.3.5 *Enclosure* temperature

Additional subclause to 6.3.5:

T.6.3.5.200 Combustible surface

When required by 4.6.5.3 and T.4.12.201 12), *BDM/CDM/PDS* must be marked with the following or equivalent wording:

> WARNING:
>
> WHEN MOUNTING ON OR OVER A COMBUSTIBLE SURFACE, A FLOOR PLATE OF AT LEAST 1,43 mm GALVANIZED OR 1,6 mm UNCOATED STEEL EXTENDED AT LEAST 150 mm BEYOND THE EQUIPMENT ON ALL SIDES MUST BE INSTALLED.

This marking need not be permanent.

T.6.3.6 Open type *BDM/CDM*

T.6.3.7 Connections

T.6.3.8 Commissioning

T.6.3.9 Protection requirements

T.6.3.9.1 *Accessible parts* and *accessible circuits*

T.6.3.9.1.1 General

Additional subclauses to 6.3.9.1.1:

T.6.3.9.1.1.200 Dead metal

A live heat sink or other part mistaken as dead metal and exposed to persons must be marked with the word "WARNING" and the following, or equivalent: "RISK OF ELECTRIC SHOCK – HEAT SINK (or other word describing the type of part) ARE LIVE – DISCONNECT POWER SUPPLY BEFORE SERVICING." The marking must be located on the *live part*.

T.6.3.9.1.1.201 Control circuit overcurrent protection

Unless *control circuit overcurrent* protection is provided in the *BDM/CDM/PDS*, a permanent marking must be provided on the *BDD/CDM/PDS* or wiring diagram to indicate that such protection is required.

T.6.3.9.2 Protective class

T.6.3.9.3 *Protective equipotential bonding* circuit

T.6.3.9.4 *Touch current* or high leakage current

T.6.3.9.5 Compatibility with RCD

T.6.3.9.6 External protection means

T.6.3.9.6.1 General

T.6.3.9.6.2 Protective devices

T.6.3.9.6.3 Protection according to IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017, Clauses 411 or 415

6.3.9.6.3 is not applicable

Additional subclauses to 6.3.9.6:

T.6.3.9.6.200 Limited short circuit current

BDM/CDM/PDS must be marked:

SUITABLE FOR USE ON A CIRCUIT CAPABLE OF DELIVERING NOT MORE THAN ____ RMS SYMMETRICAL AMPERES, ____ V MAXIMUM.

The ampere rating must be not more than the value for which the controller was tested in accordance with 5.2.4.5 or Table T.28. The marking of a *component* or sub-assembly must be permanently marked on the device; or marked on a peel-back permanent adhesive-type label provided with the device.

T.6.3.9.6.201 Branch-circuit protective devices

The marking specified in T.6.3.9.6.202 must be completed with additional information where required, as follows:

a) *BDM/CDM/PDS* tested using branch-circuit protective devices rated less than the maximum size specified in T.5.2.4.5.201 a) or d), or T.5.2.4.5.201 a) must additionally state: WHEN PROTECTED BY ___ (B) ___ WITH A MAXIMUM RATING OF ___ (C) ___ , where
   i) (B) represents the type of *overcurrent* protective devices, either "fuses" or "a circuit breaker"; and
   ii) (C) represents the maximum ampere rating of the *overcurrent* protective device used for the short-circuit test specified in T.5.2.4.5.201 3).
b) *BDM/CDM/PDS* tested in accordance with T.5.2.4.5.201 3) for high fault current test must additionally state
   i) WHEN PROTECTED BY ___ CLASS FUSES; or
   ii) WHEN PROTECTED BY A CIRCUIT BREAKER HAVING AN INTERRUPTING RATING NOT LESS THAN ___ RMS SYMMETRICAL AMPERES, ___ V MAXIMUM.

T.6.3.9.6.202 High available fault current

BDM/CDM/PDS intended for use on circuits with high available fault currents, as indicated in T.5.2.4.1.200 and T.5.2.4.5.201 must be marked with the word ATTENTION and the following or equivalent wording

THE OPENING OF THE BRANCH-CIRCUIT PROTECTIVE DEVICE MAY BE AN INDICATION THAT A FAULT HAS BEEN INTERRUPTED. TO REDUCE THE RISK OF FIRE OR ELECTRIC SHOCK, CURRENT-CARRYING PARTS AND OTHER COMPONENTS OF THE CONTROLLER SHOULD BE EXAMINED AND REPLACED IF DAMAGED. IF BURNOUT OF THE CURRENT ELEMENT OF AN OVERLOAD RELAY OCCURS, THE COMPLETE OVERLOAD RELAY MUST BE REPLACED.

T.6.3.9.6.203 Solid state short-circuit protection

BDM/CDM/PDS provided with solid state short-circuit protection in accordance with T.5.2.4.5.200 3) must be marked with the following or the equivalent:

INTEGRAL SOLID STATE SHORT-CIRCUIT PROTECTION DOES NOT PROVIDE BRANCH CIRCUIT PROTECTION. BRANCH CIRCUIT PROTECTION MUST BE PROVIDED IN ACCORDANCE WITH THE CANADIAN ELECTRICAL CODE, PART I.

T.6.3.9.7 Motor overload protection and overtemperature protection

Additional subclauses in 6.3.9.7:

T.6.3.9.7.200 Overload relay that has a replaceable current element

When an overload relay that has a replaceable current element is used, it must comply with the marking requirements of CSA C22.2 No. 14.

T.6.3.9.7.201 Automatic-reset overload relay

BDM/CDM/PDS employing an automatic-reset overload relay and supplied with a wiring diagram indicating 2-wire control must be permanently marked to indicate that a motor connected to the circuit can start.

T.6.3.9.7.202 Motors that have thermal protection

BDM/CDM/PDS intended for use only with motors that have thermal protection in or on the motors must be marked to indicate that the motors must have integral thermal protection.

T.6.3.9.7.203 Connections for thermal protection

BDM/CDM/PDS with connections for thermal protection in or on motors must identify the proper connection and the rating of the load imposed by the *BDM/CDM/PDS* on the protector contacts. The rating must be in volts and amperes, but must be in volts and volt-amperes when the load is electromagnetic. The marking must also indicate alternating or direct current.

T.6.4 Information for intended use

T.6.4.1 General

T.6.4.2 Adjustment

Additional subclause to 6.4.2:

T.6.4.2.200 Adjustable *trip* settings

Adjustable *trip* settings must be marked on the circuit breaker. If code designations are used, a table must be provided on the combination controller that specifies the ampere rating for each setting.

T.6.4.3 Labels, signs, symbols and signals

T.6.4.4 Hot surface

T.6.4.5 Control and device marking

Additional subclauses to 6.4.5:

T.6.4.5.200 Designation of the fuse

The marking must also indicate the designation of the fuse, but may also include the words OR EQUIVALENT.

T.6.4.5.201 Fuseholder

When a fuse (other than a supplemental fuse) is provided, and if the fuseholder will accept a fuse having a higher current rating, a marking specifying the maximum fuse size must be provided near the fuseholder.

Additional subclauses to 6.4:

T.6.4.200 More than one factory

When the manufacturer produces or assembles *BDM/CDM/PDS* at more than one factory, each finished item of *BDM/CDM/PDS* must have a distinctive marking, which identifies it as the product of a particular factory.

T.6.4.201 External surge suppressor

For an external surge suppressor, the PDS must be marked in visible manner with the following, or equivalent, text:

TRANSIENT SURGE SUPPRESSION SHALL BE INSTALLED ON THE LINE SIDE OF THIS EQUIPMENT AND SHALL BE RATED _____ V (PHASE TO GROUND), SUITABLE FOR OVERVOLTAGE CATEGORY _____, AND SHALL PROVIDE PROTECTION FOR A RATED IMPULSE WITHSTAND VOLTAGE PEAK OF _____ KV.

T.6.4.202 Miscellaneous

Where applicable, *BDM/CDM/PDS* shall be legibly marked as follows.

1) *Door*s and covers of compartments containing high voltage *component*s must be provided with a warning marking on the outside of the *door* or *cover* providing access, stating "DANGER HIGH VOLTAGE KEEP OUT" or "DANGER: ____ V" (with *system voltage* or voltage class inserted in the blank space).
2) The external manual release operator of a latched contactor must be marked to indicate its function.
3) Permanent, legible marking must be installed on panels or *door*s that give access to *hazardous live parts* warning of the danger of opening while energized.
4) Any barrier intended to be removed during routine maintenance or servicing (e.g., barriers required to be removed for replacement of fuses or the examination of contacts) must be marked to indicate that its reinstallation is required.

5) If the controller is designed in such a way that a *low-voltage* control circuit fuse is accessible with the CPT or potential transformers energized, a warning must be provided in the vicinity of the fuseholder: "WARNING" followed by the statement "FUSES MAY BE ENERGIZED" or the equivalent.

T.6.5 Supplementary information

T.6.5.1 General

T.6.5.2 Capacitor discharge

Addition to 6.5.2:

The marking must be located where clearly visible to the user prior to accessing the charged circuit. The marking must include the following: "WARNING – RISK OF ELECTRIC SHOCK", followed by instructions to discharge the specific capacitor or indicating the time required for the capacitor to discharge to a level below 50 V DC.

Additional clause:

T.200 IEC normative references replaced by CSA standards

In Canada, the IEC normative references listed in Table T.31 are replaced by the indicated CSA or ANSI standards.

Table T.31 – IEC normative references replaced by CSA standards

IEC standard title	IEC standard number	CSA standard title	CSA standard number
High-voltage test techniques	IEC 60034 (all part)	Motors and Generators Motors with Inherent Overheating Protection	C22.2 No.100 C22.2 No.77
Safety of machinery – Electrical equipment of machines – Part 1: General requirements	IEC 60204-1:2016, IEC 60204-1:2016/AMD1:2021	Industrial Control Equipment Industrial electrical machinery	C22.2 No. 14 C22.2 No. 301
Safety of machinery – Electrical equipment of machines – Part 11: Requirements for equipment for voltages above 1 000 V AC or 1 500 V DC and not exceeding 36 kV	IEC 60204-11:2018	Medium-voltage AC Contactors, Controllers, and Control Centres	C22.2 No. 253
High-voltage test techniques– Part 1: General definitions and test requirements	IEC 60060-1:2010	Techniques for High-Voltage Testing	ANSI / IEEE 4
Method for the determination and the proof of the comparative tracking indices of solid insulating materials	IEC 60112:2020	Evaluation of Properties of Polymeric Materials	C22.2 No. 0.17
Electrical insulating materials – Thermal endurance properties – Part 4-1: Ageing ovens – Single-chamber ovens	IEC 60216-4-1	Evaluation of Properties of Polymeric Materials	C22.2 No. 0.17
Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions	IEC 60364-1	Canadian Electrical Code, Part I	C22.1

IEC standard title	IEC standard number	CSA standard title	CSA standard number
Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock	IEC 60364-4-41:2005, IEC 60364-4-41:2005/AMD1:2017	Canadian Electrical Code, Part I	C22.1
Low voltage electrical installations– Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances	IEC 60364-4-44:2007, IEC 60364-4-44:2007/AMD 1:2015, IEC 60364-4-44:2007/AMD2:2018	Canadian Electrical Code, Part I	C22.1
Low-voltage electrical installations – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements and protective conductors	IEC 60364-5-54:2011, IEC 60364-5-54:2011/AMD1:2021	Canadian Electrical Code, Part I	C22.1
Degrees of protection provided by enclosures (IP code)	IEC 60529:1989, IEC 60529:1989/AMD1:1999, IEC 60529:1989/AMD2:2013	Degrees of protection provided by enclosures (IP code)	CAN/CSA-C22.2 No. 60529
Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests	IEC 60664-1:2020	Insulation Coordination	C22.2 No.0.2
Insulation coordination for equipment within low-voltage systems – Part 3: Use of coating, potting or moulding for protection against pollution	IEC 60664-3:2016	Insulation Coordination	C22.2 No.0.2
Insulation coordination for equipment within low-voltage systems – Part 4: Consideration of high-frequency voltage stress	IEC 60664-4:2005	Insulation Coordination	C22.2 No.0.2
Fire hazard testing – Part 2-10: Glowing/hot-wire based test methods – Glow-wire apparatus and common test procedure	IEC 60695-2-10:2021	Evaluation of Properties of Polymeric Materials	C22.2 No. 0.17
Fire hazard testing – Part 2-11: Glowing/hot-wire based test methods – Glow-wire flammability test method for end-products (GWEPT)	IEC 60695-2-11:2021	Evaluation of Properties of Polymeric Materials	C22.2 No. 0.17
Fire hazard testing – Part 2-13: Glowing/hot-wire based test methods – Glow-wire ignition temperature (GWIT) test method for materials	IEC 60695-2-13:2021	Evaluation of Properties of Polymeric Materials	C22.2 No. 0.17
Fire hazard testing – Part 10-2: Abnormal heat – Ball pressure test method	IEC 60695-10-2:2014	Evaluation of Properties of Polymeric Materials	C22.2 No. 0.17
Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods	IEC 60695-11-10:2013	Evaluation of Properties of Polymeric Materials	C22.2 No. 0.17
Fire hazard testing – Part 11-20: Test flames – 500 W flame test methods	IEC 60695-11-20:2015	Evaluation of Properties of Polymeric Materials	C22.2 No. 0.17
Automatic electrical controls – Part 1: General requirements	IEC 60730-1:2013, IEC 60730-1:2013/AMD1:2015, IEC 60730-1:2013/AMD2:2020	Automatic Electrical Controls for Household and Similar Use — Part 1: General Requirements	CAN/CSA-E60730-1-15

IEC standard title	IEC standard number	CSA standard title	CSA standard number
Low-voltage switchgear and controlgear – Part 4-1: Contactors and motor starters – Electromechanical contactors and motor-starters	IEC 60947-4-1:2018	Low-Voltage Switchgear and Controlgear — Part 4-1: Contactors and Motor-Starters — Electromechanical Contactors and Motor-Starters	CAN/CSA-C22.2 No. 60947-4-1
Low-voltage switchgear and control gear – Part 7-1: Ancillary equipment –Terminal blocks for copper conductors	IEC 60947-7-1:2009	Low-voltage switchgear and controlgear — Part 7-1: Ancillary equipment — Terminal blocks for copper conductors	CAN/CSA-C22.2 No. 60947-7-1
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Audio/video, information and communication technology equipment – Part 1: Safety requirements	IEC 62368-1:2018	Audio/Video, Information and Communication Technology Equipment — Part 1: Safety Requirements	CAN/CSA-C22.2 No. 62368-1

T.Annex P (normative)

Protection of persons against electromagnetic fields
for frequencies from 0 Hz up to 300 GHz

Modification to Annex P:

Annex P is informative.

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NFPA 70:2020, *National Electrical Code (NEC)*

NEMA 250: 2018, *Enclosures for Electrical Equipment (1000 Volts Maximum)*

UL 248-14:2000, *UL Standard for Safety Low-voltage fuses – Part 14: Supplemental fuses*

UL 347A:2015, *Standard for Medium Voltage Power Conversion Equipment*

UL 796F:2015, *UL Standard for Safety Flexible Materials Interconnect Constructions*

UL 1439:2015, *Standard for Tests for Sharpness of Edges on Equipment*

UL 61800-5-1:2012, *Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal and Energy*

Relevant component safety standards

IEC 60065:2014, *Audio, video and similar electronic apparatus – Safety requirements*

IEC 60076-1:2011, *Power transformers – Part 1: General*

IEC 60127 (all parts), *Miniature fuses*

IEC 60227 (all parts), *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V*

IEC 60245-1 (all parts), *Rubber insulated cables – Rated voltages up to and including 450/750 V*

IEC 60309-1, *Plugs, fixed or portable socket-outlets and appliance inlets for industrial purposes – Part 1: General requirements*

IEC 60317 (all parts), *Specifications for particular types of winding wires*

IEC 60384-14:2013, *Fixed capacitors for use in electronic equipment – Part 14: Sectional specification: Fixed capacitors for electromagnetic interference suppression and connection to the supply mains*

IEC 60691:2015, *Thermal-links – Requirements and application guide*

IEC 60730 (all parts), *Automatic electrical controls*

IEC 60738-1:2006, *Thermistors – Directly heated positive temperature coefficient – Part 1: Generic specification*

IEC 60747-5-5:2020*, Semiconductor devices – Part 5-5: Optoelectronic devices – Photocouplers*

IEC 60825 (all parts), *Safety of laser products*

IEC 60940:2015, *Guidance information on the application of capacitors, resistors, inductors and complete filter units for electromagnetic interference suppression*

IEC 60947 (all parts), *Low-voltage switchgear and controlgear*

IEC 60947-7-1:2009, *Low-voltage switchgear and controlgear – Part 7-1: Ancillary equipment – Terminal blocks for copper conductors*

IEC 61008 (all parts), *Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs)*

IEC 61009 (all parts), *Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs)*

IEC 61010-1:2010, *Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 1: General requirements*

IEC 61051-2:2021, *Varistors for use in electronic equipment – Part 2: Sectional specification for surge suppression varistors*

IEC 61058-1:2016, *Switches for appliances – Part 1: General requirements*

IEC 61071:2017, *Capacitors for power electronics*

IEC 61204-7:2016, *Low-voltage switch mode power supplies – Part 7: Safety requirements*

IEC 61558-2-16:2021, *Safety of transformers, reactors, power supply units and combinations thereof – Part 2-16: Particular requirements and tests for switch mode power supply units and transformers for switch mode power supply units general applications*

IEC 61810-1:2015, *Electromechanical elementary relays – Part 1: General requirements*

IEC 61984:2008, C*onnectors – Safety requirements and tests*

IEC 62368-1:2018, *Audio/video, information and communication technology equipment – Part 1: Safety requirements*

IEC 62423:2009, *Type F and type B residual current operated circuit-breakers with and without integral overcurrent protection for household and similar uses*

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SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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ENTRAÎNEMENTS ÉLECTRIQUES DE PUISSANCE À VITESSE VARIABLE –

Partie 5-1: Exigences de sécurité – Électrique, thermique et énergétique

AVANT-PROPOS

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9) L'attention est attirée sur le fait que certains des éléments de la présente Publication de l'IEC peuvent faire l'objet de droits de brevet. L'IEC ne saurait être tenue pour responsable de ne pas avoir identifié de tels droits de brevets.

L'IEC 61800-5-1 a été établie par le sous-comité 22G: Systèmes d'entraînement électrique de puissance à vitesse variable (PDS), du comité d'études 22 de l'IEC: Systèmes et équipements électroniques de puissance.

Cette troisième édition annule et remplace la deuxième édition parue en 2007 et l'Amendement 1:2016. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) harmonisation avec l'IEC 62477-1:2022;
b) harmonisation avec l'UL 61800-5-1 et la CSA C22.2 N° 274, incluant une annexe contenant une liste des divergences nationales qui ont été considérées comme étant impossibles à harmoniser dans un délai raisonnable;
c) informations plus détaillées relatives à l'évaluation des composants selon l'IEC 61800-5-1 et les normes pertinentes relatives aux composants de sécurité;
d) exigences mises à jour concernant les dangers mécaniques, y compris plusieurs classifications IP.

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
22G/455/FDIS	22G/457/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Le présent document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/publications.

Dans le présent document, les termes en *italique* sont définis à l'Article 3.

L'attention du lecteur est attirée sur le fait que l'Annex S et l'Annex T énumèrent tous les articles traitant des différences inhérentes à certains pays à caractère moins permanent par rapport au sujet du présent document.

Une liste de toutes les parties de la série IEC 61800, publiées sous le titre général *Entraînements électriques de puissance à vitesse variable,* se trouve sur le site web de l'IEC.

Le comité a décidé que le contenu du présent document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous "webstore.iec.ch" dans les données relatives au document recherché. À cette date, le document sera

- reconduit,
- supprimé,
- remplacé par une édition révisée, ou
- amendé.

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Le contenu du corrigendum 1 (2023-09) a été pris en considération dans cet exemplaire.

INTRODUCTION

0.1 Généralités

Le présent document contient la révision de l'IEC 61800-5-1:2007 et de l'IEC 61800-5-1:2007/AMD1:2016.

Plusieurs enjeux importants ont orienté le périmètre et la démarche choisie pour la maintenance de l'IEC 61800-5-1:2007 lors du développement du présent document.

Les modifications majeures par rapport à l'IEC 61800-5-1:2007 sont les suivantes.

a) **La structure et le contenu s'appuient sur l'IEC 62477-1 en ce qui concerne les modifications et les nouvelles rubriques, telles que**

- l'Article 1: Domaine d'application mis à jour pour inclure *BDM/CDM/PDS* d'émission et de transmission radio.
- 4.1, 5.1, 6.1: "Utilisation prévue" incluse.
- 4.2: Analyse du fonctionnement anormal et des conditions de premier défaut (retravaillé de manière significative).
- 4.3: Protection contre les courts-circuits et les surcharges incluse en tant que nouveau paragraphe.
- 4.4 et l'Annex A: Protection contre les chocs électriques mis à jour selon l'IEC 61140 (2016) et l'IEC 60364-4-41, y compris la coordination de l'isolement selon l'IEC 60664 (toutes les parties) en prenant en considération:
  - 4.4.2 – Classe de tension déterminante (en particulier CTD As pour les conditions sèche, humide et humide et salée); le Tableau 2 et le Tableau 3 retravaillés;
  - 4.4.3 – Protection principale (retravaillé);
  - 4.4.4 – Protection en cas de défaut (retravaillé);
  - 4.4.5 – Protection renforcée (retravaillé);
  - 4.4.7 – Isolation (retravaillé):
    - 4.4.7.1.2 – Tension de fonctionnement (nouveau);
    - 4.4.7.1.8 – Isolation par pontage des composants (nouveau);
    - 4.4.7.7 – *distance d'isolement* et *lignes de fuite* d'une carte de circuit imprimé et des ensembles de composants pour une isolation fonctionnelle (retravaillé);
    - 4.4.7.8 – Isolation solide (nouveau/retravaillé);
    - 4.4.7.9 – Raccordement des parties de l'isolation solide (joints scellés) (nouveau);
  - 4.4.8/l'Annex H – Compatibilité avec les DDR (retravaillés);
  - 4.4.10 – Conditions d'accès pour un *PDS haute tension* (nouveau).
- 4.5: Protection contre les dangers dus à l'énergie (nouveau).
- 4.6: Protection contre les dangers d'incendie et thermiques (nouveau).
- 4.7: Protection contre les dangers mécaniques (nouveau).
- 4.8: *BDM/CDM/PDS* à plusieurs sources d'alimentation (nouveau).
- 4.9: Protection contre les contraintes environnementales (nouveau) (aligné sur l'IEC 61800-2).
- 4.11: Câblage et raccordements mis à jour (retravaillé de manière significative).
- 4.12: Enveloppe mise à jour (retravaillé de manière significative).
- 4.13 Bibliographie: Évaluation des composants (nouveaux).

- 4.14 Annex P: Protection contre les champs électromagnétiques (nouveaux).
- l’Article 5: Mis à jour avec quelques exigences d'essai supplémentaires/modifiées:
  - 5.2.2.2 – Essai de non-accessibilité (retravaillé de manière significative);
  - 5.2.2.3 – Essai d'intégrité de l'enveloppe (classification IP) (retravaillé de manière significative);
  - 5.2.2.4 – Essais d'intégrité de l'enveloppe (nouveau);
  - 5.2.2.5 – Essai des *BDM/CDM/PDS* fixés au mur ou au plafond (nouveau);
  - 5.2.2.6 – Essai de fixation des poignées et organes de contrôle manuels (nouveau);
  - 5.2.2.7 – Essai de relâchement des contraintes (nouveau);
  - 5.2.3.7 – Essai de mesure du courant de contact (retravaillé);
  - 5.2.3.9 – Source de puissance limitée (nouveau);
  - 5.2.3.11 – Essai de la liaison équipotentielle de protection (nouveau);
  - 5.2.3.12 – Essai à l'entrée du circuit (nouveau);
  - 5.2.3.13 – Procédure d'essai normalisée – matériau pelliculé (nouveau);
  - 5.2.3.14 – Procédure d'essai pour la détermination de la tension de fonctionnement (nouveau);
  - 5.2.3.16 – Préconditionnement de matériau (retravaillé);
  - 5.2.4.4 – Essai de court-circuit de la liaison équipotentielle de protection (nouveau);
  - 5.2.4.9 – Essai de surcharge en sortie (nouveau);
  - 5.2.4.13.5 – Couverture des ouvertures pour l'essai d'air de refroidissement (essai de type) (nouveau);
  - 5.2.5.6 – Essai des joints scellés (nouveau);
  - 5.2.7 – Essai de pression hydrostatique (nouveau);
  - 5.2.8 – Essai de champs électromagnétiques (CEM) (nouveau).
- l’Article 6: – Mise à jour avec un marquage plus spécifique.
  - Structure alignée sur l’IEC 62477-1 de façon la plus étroite possible;
  - Tableau 48 simplifié.
- Annex A – Informations supplémentaires relatives à la protection contre les chocs électriques (retravaillée).
- Annex C – Symboles référencés (retravaillée).
- Annex E – Correction d'altitude pour les *distances d'isolement* (retravaillée).
- Annex F – Détermination de la *distance d’isolement* et de la *ligne de fuite* pour des fréquences supérieures à 30 kHz (retravaillée).
- Annex H – Lignes directrices relatives à la compatibilité des DDR (retravaillée).
- Annex M – Doigt d'épreuve pour la détermination de l'accès (nouvelle).
- Annex O – Guide pour la détermination des *distances d’isolement* et des *lignes de fuite* (nouvelle).
- Annex P – Protection des personnes contre les champs électromagnétiques pour des fréquences comprises entre 0 Hz et 300 GHz (nouvelle).
- Annex Q – Déconnexion automatique de l'alimentation (nouvelle).
- Annex R – Évaluation des risques du Guide 116 incluse (nouvelle).
- Bibliographie – Normes pertinentes en matière de sécurité des composants (nouvelle).

b) Harmonisation avec l'UL 61800-5-1

L'ensemble du document a été modifié en tenant compte des divergences nationales pour les États-Unis de l'UL 61800-5-1. Les divergences nationales pour les États-Unis de l'UL 61800-5-1 impossibles à harmoniser ont été placées dans l'Annex S.

c) Harmonisation avec la CSA C22.2 N° 274

- Compte tenu du délai court, seules quelques rubriques ont été harmonisées.
- Les divergences nationales canadiennes de la CSA 22.0 N°274 impossibles à harmoniser ont été placées dans l'Annex T.

d) Harmonisation avec l'UL 347A

- Quelques rubriques pertinentes ont été harmonisées en prenant en considération les aspects de sécurité relatifs aux *BDM/CDM/PDS haute tension.*

Une harmonisation plus importante de l'IEC 61800-5-1 est attendue. Dans ce cadre, les futures éditions de l'IEC 61800-5-1 prendra en considération le contenu de l'UL 61800-5-1, de la CSA C22.2 N° 274 et de l'UL 347A.

0.2 Commentaires du secteur industriel et des comités nationaux

L'utilisation de l'IEC 61800-5-1:2007 par les fabricants et les organismes d'essai depuis sa publication a permis d'identifier plusieurs sujets considérés comme étant utiles à la mise en œuvre ou des sujets qui nécessitent des informations supplémentaires pour une meilleure compréhension de l'intention de l'exigence spécifique. Ces sujets sont également mis en œuvre dans le présent document.

0.3 Exigences couvertes par les autres parties pertinentes de la série IEC 61800

- les exigences générales pour les *systèmes d'entraînement de puissance* en courant continu sont couvertes par l'IEC 61800-1;
- les exigences générales pour les *systèmes d'entraînement de puissance* en courant alternatif sont couvertes par l'IEC 61800-2;
- les aspects relatifs à la CEM sont couverts par l'IEC 61800-3;
- les aspects relatifs à la sécurité fonctionnelle sont couverts par l'IEC 61800-5-2;
- les aspects relatifs à la sécurité fonctionnelle des codeurs sont couverts par l'IEC 61800-5-3;
- les aspects relatifs au type de régime de charge sont couverts par l'IEC TR 61800-6;
- Les aspects relatifs aux profils de communication sont couverts par l'IEC 61800-7 (toutes les parties);
- les aspects relatifs à la tension de l'*interface de puissance* sont couverts par l'IEC TS 61800-8;
- les aspects relatifs à l'écoconception sont couverts par l'IEC 61800-9 (toutes les parties);

Le document suivant ne fait pas partie de la série IEC 61800, mais il est souvent utilisé comme partie intégrante du BDM:

- les convertisseurs à alimentation active sont couverts par l'IEC TS 62578.

ENTRAÎNEMENTS ÉLECTRIQUES DE PUISSANCE À VITESSE VARIABLE –

Partie 5-1: Exigences de sécurité – Électrique, thermique et énergétique

1 Domaine d'application

La présente partie de l'IEC 61800 spécifie les exigences relatives aux *entraînements électriques de puissance* (*PDS – power drive system*) à vitesse variable ou leurs éléments, en ce qui concerne les dangers électriques, thermiques, d'incendie, mécaniques et énergétiques, et d'autres risques appropriés. Elle ne couvre pas le matériel entraîné, à l'exception des exigences relatives aux interfaces. Elle s'applique aux *PDS* à vitesse variable qui incluent la conversion de puissance, la commande de *module d'entraînement principal (BDM)/module d'entraînement complet (CDM)* et un ou plusieurs moteurs.

Les *BDM/CDM* pour les véhicules électriques et les véhicules de traction sont exclus.

Elle s'applique aux *PDS* électriques à vitesse variable basse tension destinés à alimenter un ou plusieurs *moteurs* à partir d'un *BDM/CDM* relié à des tensions entre phases allant jusqu'à 1,0 kV inclus en courant alternatif (50 Hz ou 60 Hz) et jusqu'à 1,5 kV inclus en courant continu.

Elle s'applique également aux *PDS* électriques à vitesse variable haute tension destinés à alimenter un ou plusieurs *moteurs* à partir d'un *BDM/CDM* relié à des tensions entre phases allant jusqu'à 35 kV inclus en courant alternatif (50 Hz ou 60 Hz) et jusqu'à 52 kV inclus en courant continu.

NOTE 1 Au moment de la publication du présent document, la limite de tension technique supérieure des moteurs en courant continu est de 2,25 kV en courant continu.

NOTE 2 Les limites de tension et de fréquence ci-dessus reflètent le domaine d'application de l'IEC 61800-1 et de l'IEC 61800-2.

NOTE 3 Pour les *PDS* électriques à vitesse variable non couverts par le domaine d'application du présent document, les exigences applicables d'autres normes (l'IEC 62477-1 et l'IEC 62477-2, par exemple) peuvent être utilisées.

Le présent document s'applique également aux *PDS* qui émettent ou reçoivent intentionnellement des ondes radioélectriques pour les besoins de la communication radio.

Les moteurs pour matériels entraînés (voir la Figure 1) sont couverts par l'IEC 60034 (toutes les parties).

NOTE 4 Dans certains cas, les exigences de sécurité du *PDS* (par exemple la protection contre l'accès aux parties dangereuses) peuvent nécessiter l'utilisation de composants spéciaux et/ou de mesures supplémentaires.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60034 (toutes les parties), *Machines électriques tournantes*

IEC 60034-1:2022, *Machines électriques tournantes – Partie 1: Caractéristiques assignées et caractéristiques de fonctionnement*

IEC 60034-5:2020, *Machines électriques tournantes – Partie 5: Degrés de protection procurés par la conception intégrale de machines électriques tournantes (code IP) – Classification*

IEC 60050-112, *Vocabulaire électronique international (IEV) – Partie 112: Grandeurs et unités* (disponible à l'adresse suivante: www.electropedia.org)

IEC 60050-113, *Vocabulaire électronique international (IEV) – Partie 113: Physique pour l'électrotechnique* (disponible à l'adresse suivante: www.electropedia.org)

IEC 60050-114, *Vocabulaire électronique international (IEV) – Partie 114: Électrochimie* (disponible à l'adresse suivante: www.electropedia.org)

IEC 60050-131, *Vocabulaire électronique international (IEV) – Partie 131: Théorie des circuits* (disponible à l'adresse suivante: www.electropedia.org)

IEC 60050-151, *Vocabulaire électronique international (IEV) – Partie 151: Dispositifs électriques et magnétiques* (disponible à l'adresse suivante: www.electropedia.org)

IEC 60050-161, *Vocabulaire électronique international (IEV) – Partie 161: Compatibilité électromagnétique* (disponible à l'adresse suivante: www.electropedia.org)

IEC 60050-192, *Vocabulaire électronique international (IEV) – Partie 192: Sûreté de fonctionnement* (disponible à l'adresse suivante: www.electropedia.org)

IEC 60050-426, *Vocabulaire électronique international (IEV) – Partie 426: Atmosphères explosives* (disponible à l'adresse suivante: www.electropedia.org)

IEC 60050-441, *Vocabulaire électronique international (IEV) – Partie 441: Appareillage et fusibles* (disponible à l'adresse suivante: www.electropedia.org)

IEC 60050-442, *Vocabulaire électronique international (IEV) – Partie 442: Petit appareillage* (disponible à l'adresse suivante: www.electropedia.org)

IEC 60050-551, *Vocabulaire électronique international (IEV) – Partie 551: Électronique de puissance* (disponible à l'adresse suivante: www.electropedia.org)

IEC 60050-601, *Vocabulaire électronique international (IEV) – Partie 601: Production, transport et distribution de l'énergie électrique – Généralités* (disponible à l'adresse suivante: www.electropedia.org)

IEC 60050-826, *Vocabulaire électronique international (IEV) – Partie 826: Installations électriques* (disponible à l'adresse suivante: www.electropedia.org)

IEC 60050-903, *Vocabulaire électronique international (IEV) – Partie 903: Appréciation du risque* (disponible à l'adresse suivante: www.electropedia.org)

IEC 60068-2-1:2007, *Essais d'environnement– Partie 2-1: Essais – Essai A: Froid*

IEC 60068-2-2:2007, *Essais d'environnement – Partie 2-2: Essais – Essai B: Chaleur sèche*

IEC 60068-2-6:2007, *Essais d'environnement – Partie 2-6: Essais – Essai Fc: Vibrations (sinusoïdales)*

IEC 60068-2-30:2005, *Essais d'environnement – Partie 2-30: Essais – Essai Db: Essai cyclique de chaleur humide (cycle de 12 h + 12 h)*

IEC 60068-2-52:2017, *Essais d'environnement – Partie 2-52: Essais – Essai Kb: Brouillard salin, essai cyclique (solution de chlorure de sodium)*

IEC 60068-2-68:1994, *Essais d'environnement – Partie 2-68: Essais – Essai L: Poussière et sable*

IEC 60068-2-78:2012, *Essais d'environnement – Partie 2-78: Essais – Essai Cab: Chaleur humide, essai continu*

IEC 60204-11:2018, *Sécurité des machines – Équipement électrique des machines – Partie 11: Exigences pour les équipements fonctionnant à des tensions supérieures à 1 000 V en courant alternatif ou 1 500 V en courant continu et ne dépassant pas 36 kV*

IEC 60320 (toutes les parties), *Connecteurs pour usages domestiques et usages généraux analogues*

IEC 60364 (toutes les parties), *Installations électriques à basse tension*

IEC 60364-4-41:2005, *Installations électriques à basse tension – Partie 4-41: Protection pour assurer la sécurité – Protection contre les chocs électriques*
IEC 60364-4-41:2005/AMD1:2017

IEC 60364-5-54:2011, *Installations électriques à basse tension – Partie 5-54: Choix et mise en œuvre des matériels électriques – Installations de mise à la terre et conducteurs de protection*
IEC 60364-5-54:2011/AMD1:2021

IEC 60417, *Symboles graphiques utilisables sur le matériel* (disponible à l'adresse suivante: http://www.graphical-symbols.info/equipment)

IEC 60529:1989, *Degrés de protection procurés par les enveloppes (Code IP)*
IEC 60529:1989/AMD1:1999
IEC 60529:1989/AMD2:2013

IEC 60617, *Symboles graphiques pour schémas* (disponible à l'adresse suivante: http://std.iec.ch/iec60617)

IEC 60664-1:2020, *Coordination de l'isolement des matériels dans les réseaux d'énergie électrique à basse tension – Partie 1: Principes, exigences et essais*

IEC 60664-3:2016, *Coordination de l'isolement des matériels dans les systèmes (réseaux) à basse tension – Partie 3: Utilisation de revêtement, d'empotage ou de moulage pour la protection contre la pollution*

IEC 60664-4:2005, *Coordination de l'isolement des matériels dans les systèmes (réseaux) à basse tension – Partie 4: Considérations sur les contraintes de tension à haute fréquence*

IEC 60695-2-10:2021, *Essais relatifs aux risques du feu – Partie 2-10: Essais au fil incandescent/chauffant – Appareillage et méthode commune d'essai*

IEC 60695-2-11:2021, *Essais relatifs aux risques du feu – Partie 2-11: Essais au fil incandescent/chauffant – Méthode d'essai d'inflammabilité pour produits finis (GWEPT))*

IEC 60695-2-13:2021, *Essais relatifs aux risques du feu – Partie 2-13: Essais au fil incandescent/chauffant – Méthode d'essai de température d'allumage au fil incandescent (GWIT) pour matériaux*

IEC 60695-10-2:2014, *Essais relatifs aux risques du feu – Partie 10-2: Chaleurs anormales – Essai à la bille*

IEC 60695-11-10:2013, *Essais relatifs aux risques du feu – Partie 11-10: Flammes d'essai – Méthodes d'essai horizontale et verticale à la flamme de 50 W*

IEC 60695-11-20:2015, *Essais relatifs aux risques du feu – Partie 11-20: Flammes d'essai – Méthode d'essai à la flamme de 500 W*

IEC 60721-3-3:1994, *Classification des conditions d'environnement – Partie 3-3: Classification des groupements des agents d'environnement et de leurs sévérités – Utilisation à poste fixe, protégé contre les intempéries*[1]
IEC 60721-3-3:1994/AMD1:1995
IEC 60721-3-3:1994/AMD2:1996

IEC 60721-3-4:2019, *Classification des conditions d'environnement – Partie 3: Classification des groupements des agents d'environnement et de leurs sévérités – Utilisation à poste fixe, non protégé contre les intempéries*

IEC 60730-1:2013, *Dispositifs de commande électrique automatiques – Partie 1: Exigences générales*
IEC 60730-1:2013/AMD1:2015
IEC 60730-1:2013/AMD2:2020

IEC 60755:2017, *General safety requirements for residual current operated protective devices* (disponible en anglais seulement)

IEC 60799:2018, *Petit appareillage électrique – Cordons-connecteurs et cordons-connecteurs d'interconnexion*

IEC 60947-4-1:2018, *Appareillage à basse tension – Partie 4-1: Contacteurs et démarreurs de moteurs – Contacteurs et démarreurs électromécaniques*

IEC 60990:2016, *Méthodes de mesure du courant de contact et du courant dans le conducteur de protection*

IEC 61032:1997, *Protection des personnes et des matériels par les enveloppes – Calibres d'essai pour la vérification*

IEC 61084 (toutes les parties), *Systèmes de goulottes et systèmes de conduits-profilés pour installations électriques*

IEC 61180:2016, *Techniques des essais à haute tension pour matériels à basse tension – Définitions, exigences et modalités relatives aux essais, matériel d'essai*

IEC 61189-3:2007, *Méthodes d'essai pour les matériaux électriques, les cartes imprimées et autres structures d'interconnexion et ensembles – Partie 3: Méthodes d'essai des structures d'interconnexion (cartes imprimées)*

IEC 61230:2008, *Travaux sous tension – Équipements portables de mise à la terre ou de mise à la terre et en court-circuit*

IEC 61386 (toutes les parties), *Systèmes de conduits pour la gestion du câblage*

1 Cette publication a été retirée.

IEC 61558-1:2017, *Sécurité des transformateurs, bobines d'inductance, blocs d'alimentation et des combinaisons de ces éléments – Partie 1: Exigences générales et essais*

IEC 62109-1:2010, *Sécurité des convertisseurs de puissance utilisés dans les systèmes photovoltaïques – Partie 1: Exigences générales*

IEC 62271-102:2018, *Appareillage à haute tension – Partie 102: Sectionneurs et sectionneurs de terre à courant alternatif*

IEC 62477-1:2022, *Exigences de sécurité applicables aux systèmes et matériels électroniques de conversion de puissance – Partie 1: Généralités*

IEC 62477-2:2018, *Exigences de sécurité applicables aux systèmes et matériels électroniques de conversion de puissance – Partie 2: Convertisseurs électroniques de puissance entre 1 000 V en courant alternatif ou 1 500 V en courant continu et 36 kV en courant alternatif ou 54 kV en courant continu*

ISO 3864-1:2011, *Symboles graphiques – Couleurs de sécurité et signaux de sécurité – Partie 1: Principes de conception pour les signaux de sécurité et les marquages de sécurité*

ISO 3746:2010, *Acoustique – Détermination des niveaux de puissance acoustique et des niveaux d'énergie acoustique émis par les sources de bruit à partir de la pression acoustique – Méthode de contrôle employant une surface de mesure enveloppante au-dessus d'un plan réfléchissant*

ISO 7000, *Symboles graphiques utilisables sur le matériel* (disponible à l'adresse suivante: http://www.graphical-symbols.info/equipment)

ISO 7010, Symboles graphiques – *Couleurs de sécurité et signaux de sécurité – Signaux de sécurité enregistrés* (disponible à l'adresse suivante: https://www.iso.org/obp)

ISO 9614-1:1993, *Acoustique – Détermination par intensimétrie des niveaux de puissance acoustique émis par les sources de bruit – Partie 1: Mesurages par points*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions de l'IEC 60050-112:2010, l'IEC 60050-113:2011, l'IEC 60050-114:2014, l'IEC 60050-131:2002, l'IEC 60050-426:2020, l'IEC 60050-151:2001, l'IEC 60050-161:1990, l'IEC 60050-192:2015, l'IEC 60050-441:1984, l'IEC 60050-442:1998, l'IEC 60050-551:1998, l'IEC 60050-601:1985, l'IEC 60050-826, l'IEC 60050-903:2013 et l'IEC 60664-1:2020 ainsi que les suivants s'appliquent.

Le Tableau 1 fournit une liste de référence alphabétique des différents termes utilisés.

Tableau 1 – Liste alphabétique des termes (dans l'ordre alphabétique des termes anglais)

Terme	Numéro du terme	Terme	Numéro du terme	Terme	Numéro du terme
condition anormale de fonctionnement (fonctionnement anormal)	3.1	protection en cas de défaut	3.33	protection de classe II	3.65
partie accessible	3.2	borne pour câblage externe	3.34	protection de classe III	3.66
accessoire	3.3	enveloppe ignifuge	3.35	mise à la terre de protection (PE)	3.67
circuit adjacent	3.4	isolation fonctionnelle	3.36	conducteur de mise à la terre de protection	3.68
température ambiante	3.5	BDM/CDM/PDS portatif (à main)	3.37	impédance de protection	3.69
module d'entraînement principal (BDM)	3.6	zone d'accès général	3.38	isolation renforcée	3.70
isolation principale	3.7	partie active dangereuse	3.39	zone d'accès limité	3.71
protection principale	3.8	BDM/CDM/PDS haute tension	3.40	essai individuel de série	3.72
contournement	3.9	panneau articulé	3.41	essai sur prélèvement	3.73
courant de sortie assigné BDM/CDM	3.10	installation	3.42	circuit TBTP	3.74
distance d'isolement	3.11	PDS intégré	3.43	zone d'accès pour la maintenance	3.75
circuit de commande	3.12	verrouillage	3.44	protection de secours contre les courts-circuits	3.76
essai de mise en service essai de recette	3.13	partie active partie sous tension	3.45	dispositif de protection contre les courts-circuits (DPCC)	3.77
module d'entraînement complet (CDM)	3.14	basse tension (BT)	3.46	courant de courte durée admissible (I_{cw})	3.78
composant	3.15	BDM/CDM/PDS basse tension	3.47	personne qualifiée	3.79
courant conditionnel de court-circuit (I_{cc})	3.16	réseau	3.48	condition de premier défaut	3.80
capot	3.17	valeur minimale exigée du courant de court-circuit présumé ($I_{cp,mr}$)	3.49	isolation solide	3.81
ligne de fuite	3.18	déplaçable	3.50	température de l'air ambiant environnant	3.82
classe de tension déterminante (CTD)	3.19	alimentation non raccordée directement au réseau	3.51	environnement	3.83
porte	3.20	type ouvert	3.52	isolation supplémentaire	3.84
double isolation	3.21	personne ordinaire	3.53	dispositif de protection contre les surtensions (SPD) parafoudre	3.85
BDM/CDM/PDS à enficher directement BDM/CDM/PDS enfichable directement	3.22	courant de court-circuit en sortie	3.54	système	3.86
CTD As	3.23	surintensité	3.55	tension système	3.87
claquage électrique	3.24	circuit TBTP	3.56	surtension temporaire	3.88
isolation électrique (isolation)	3.25	équipement relié en permanence	3.57	mémoire thermique	3.89

Terme	Numéro du terme	Terme	Numéro du terme	Terme	Numéro du terme
écran de protection électrique (écran de protection)	3.26	équipement enfichable de type A matériel du type A raccordé par prise de courant	3.58	rétention de mémoire thermique	3.90
protection électronique contre les surcharges du moteur	3.27	équipement enfichable de type B matériel du type B raccordé par prise de courant	3.59	courant de contact	3.91
protection contre les courts-circuits en sortie de puissance (circuit électronique)	3.28	accès	3.60	déclenchement	3.92
enveloppe	3.29	entraînement électrique de puissance (PDS)	3.61	essai de type	3.93
protection renforcée	3.30	courant de court-circuit présumé (I_{cp})	3.62	inspection visuelle	3.94
durée de vie prévue	3.31	liaison équipotentielle de protection	3.63	tension de fonctionnement	3.95
très basse tension (TBT)	3.32	protection de classe I	3.64	zone de liaison équipotentielle	3.96

3.1
condition anormale de fonctionnement
fonctionnement anormal
condition de fonctionnement temporaire qui n'est ni une condition normale de fonctionnement ni une *condition de premier défaut* de l'équipement proprement dit

Note 1 à l'article: Des *conditions anormales de fonctionnement* peuvent être induites par l'équipement ou par une personne et peuvent entraîner le dysfonctionnement d'un *composant*, d'un dispositif ou de l'*isolation*.

[SOURCE: IEC 62368-1:2010, 3.3.7.1, IEV 903-01-22, modifié – Note 1 à l'article supprimée et Notes 2 et 3 à l'article combinées.]

3.2
partie accessible
partie ou surface qui peut être touchée au moyen du calibre d'essai B de l'IEC 61032, et si la partie ou surface est métallique, toute partie conductrice qui lui est raccordée

Note 1 à l'article: Le calibre d'essai B est traité dans l'IEC 61032:1997, Figure 2. Voir également la Figure M.2.

Note 2 à l'article: Les parties non métalliques accessibles avec des revêtements conducteurs sont considérées comme étant des parties métalliques accessibles.

[SOURCE: IEC 60335-1:2020, 3.6.3, modifié – Note 1 à l'article ajoutée.]

3.3
accessoire
partie, composant ou équipement additionnel destiné à étendre les capacités du BDM/CDM/PDS, mais non exigé pour la fonction générale du BDM/CDM/PDS

Note 1 à l'article: Des exemples types sont:

- les bobines d'inductance et les filtres RFI externes,
- les filtres externes de sortie côté moteur,
- kits d'interface de communication, de commande ou d'entrée/de sortie,
- SPD externe pour la réduction des transitoires,
- kits ou parties additionnel(le)s d'*enveloppes*,
- kits de ventilation additionnels,
- liaison mécanique ou kits de support de câbles, ou
- dispositif, instrument de mesure additionnel, etc.

Note 2 à l'article: Les capacités étendues sont considérées comme étant des caractéristiques électriques, mécaniques, thermales ou de bruit acoustique du *BDM/CDM/PDS* lorsqu'il est installé et fonctionne comme cela est prévu.

Note 3 à l'article: Les *accessoires* et les kits d'*accessoires* peuvent être installés en usine ou sur le terrain.

3.4
circuit adjacent
circuit suivant le circuit à l'étude ayant une exigence applicable à l'*isolation fonctionnelle*, *l'isolation principale*, la *double isolation* ou l'*isolation renforcée* entre eux à des fins de protection

3.5
température ambiante
température moyenne de l'air ou du milieu au voisinage du matériel

Note 1 à l'article: Pendant la mesure de la *température ambiante*, il est recommandé que l'instrument/la sonde de mesure soit protégé(e) des courants d'air et de la chaleur rayonnée.

Note 2 à l'article: Le "matériel" inclut le *BDM/CDM/PDS* et les *composants*, en fonction de l'application du terme *température ambiante*.

Note 3 à l'article: En règle générale, la *température ambiante* est mesurée à proximité du matériel (environ 50 mm à 100 mm), protégée du rayonnement thermique et mesurée à une hauteur d'environ 50 % de la hauteur du matériel dans le cas des matériels à refroidissement passif ou au niveau de l'amenée d'air du matériel à refroidissement actif.

[SOURCE: IEC 60050-826:2004, 826-10-03, modifié – Notes 2 et 3 à l'article ajoutées.]

3.6
module d'entraînement principal
BDM
convertisseur électronique de puissance et commande associée, connecté entre une source d'alimentation électrique et un moteur

Note 1 à l'article: Le *BDM* est capable de transmettre l'énergie de la source d'alimentation électrique au moteur et peut être également capable de transmettre l'énergie produite par le moteur à la source d'alimentation électrique.

Note 2 à l'article: Le *BDM* commande tout ou partie des paramètres suivants relatifs à l'énergie transmise au moteur et à celle fournie par celui-ci: courant, fréquence, tension, vitesse, couple et force.

Note 3 à l'article: L'abréviation "BDM" est dérivée du terme anglais développé correspondant "*basic drive module*".

[SOURCE: IEC 61800-2:2021, 3.4]

3.7
isolation principale
isolation des *parties actives dangereuses* qui assure la *protection principale*

Note 1 à l'article: Cette notion n'est pas applicable à l'*isolation* exclusivement utilisée à des fins fonctionnelles.

[SOURCE: IEC 60050-195:2021, 195-06-06, modifié – “des parties actives dangereuses” ajouté.]

3.8
protection principale
protection contre les chocs électriques en l'absence de défaut au moyen d'une *isolation*, d'une distance ou d'une combinaison des deux

[SOURCE: IEC 60050-195:1998, 195-06-01, modifié – “dans des conditions normales” remplacé par “en l'absence de défaut au moyen d'une *isolation*, d'une distance ou d'une combinaison des deux".]

3.9
contournement
circuit qui, lorsqu'il est fermé, génère un trajet alternatif pour la circulation du courant parallèlement au circuit contourné

Note 1 à l'article: Le *circuit de contournement* est en général composé d'un commutateur ou d'un contacteur.

Note 2 à l'article: Le *circuit de contournement* permet de désactiver le circuit d'origine lors du maintien de la circulation de courant vers la charge.

3.10
courant de sortie assigné BDM/CDM
courant côté moteur du *BDM/CDM* qui peut être fourni en permanence sans dépasser les limites définies, dans les conditions de fonctionnement assignées

Note 1 à l'article: Pour le *BDM/CDM* en courant alternatif, il s'agit d'une valeur efficace. Pour le *BDM/CDM* en courant continu, il s'agit d'une valeur moyenne.

Note 2 à l'article: Ce terme est issu de l’IEC 61800-1:2021 et modifié. Il est conforme à l’IEC 61800-2:2021.

3.11
distance d’isolement
plus petite distance dans l’air entre deux parties conductrices

Note 1 à l'article: Cette distance peut être mesurée le long d’un fil tendu suivant le plus court trajet possible entre ces deux parties conductrices.

[SOURCE: IEC 60050-581:2008, 581-27-76, modifié – Note à l’article ajoutée.]

3.12
circuit de commande
circuit qui transporte les signaux pour assurer les performances d'un *BDM/CDM/PDS* et qui n'est pas le circuit d'alimentation principal

3.13
essai de mise en service
essai de recette
essai d'un dispositif ou d'un équipement, effectué sur son lieu d'implantation, et destiné à vérifier son *installation* correcte et son bon état de marche

[SOURCE: IEC 60050-411:1996, 411-53-06, modifié – "d’une machine" remplacé par "d’un dispositif".]

3.14
module d’entraînement complet
CDM
module d’entraînement comprenant, y compris entre autres, le *BDM* et des composants associés, tels que des dispositifs de protection, des transformateurs et des dispositifs auxiliaires, à l'exclusion toutefois du moteur et des capteurs mécaniquement couplés à l'arbre du moteur

Note 1 à l'article: L'abréviation "CDM" est dérivée du terme anglais développé correspondant "*complete drive module*".

[SOURCE: IEC 61800-2:2021, 3.6]

3.15
composant
partie du *BDM/CDM/PDS*, ne pouvant être fractionnée matériellement sans perdre sa fonction particulière

Note 1 à l'article: Les termes "*composant"* et "sous-ensemble" utilisés dans le présent document doivent être lus dans leur contexte. Un *composant* peut donc être un condensateur simple, un bloc d'alimentation, constitué de plusieurs *composants* électroniques et d'un module d’entraînement complet à l'intérieur d'une armoire.

Note 2 à l'article: Un étage onduleur (module) peut également être considéré comme un sous-ensemble d'un module d’entraînement.

[SOURCE: IEC 60050-151:2001, 151-11-21, modifié –"partie constitutive d'un dispositif" remplacé par "partie du *BDM/CDM/PDS*", et notes à l’article ajoutées.]

3.16
courant conditionnel de court-circuit
$I_{\mathbf{cc}}$
valeur efficace d'un *courant de court-circuit présumé* disponible à partir d'une source d'alimentation, déclarée par le fabricant du *BDM/CDM/PDS* dans les conditions spécifiées, utilisant un type particulier de *dispositif de protection contre les courts-circuits* (SCPD) assurant la protection du *BDM/CDM/PDS*

Note 1 à l'article: Le *dispositif de protection contre les courts-circuits* peut faire partie intégrante du BDM/CDM/PDS ou peut être une unité distincte.

3.17
capot
partie non articulée d'une *enveloppe* qui ferme une ouverture

3.18
ligne de fuite
distance la plus courte, le long de la surface d'un isolant solide, entre deux parties conductrices

[SOURCE: IEC 60050-151:2001, 151-15-50]

3.19
classe de tension déterminante
CTD
classification de la gamme de tensions utilisée afin de déterminer les mesures de protection contre les chocs électriques et les exigences d'*isolation* entre les circuits

3.20
porte
partie articulée d'une *enveloppe* couvrant une ouverture, et qui est destinée à être ouverte pendant la maintenance de routine, les manœuvres et les réglages

3.21
double isolation
isolation comprenant à la fois une *isolation principale* et une *isolation supplémentaire*

[SOURCE: IEC 60050-195:2021, 195-06-08]

3.22
***BDM/CDM/PDS* à enficher directement**
***BDM/CDM/PDS* enfichable directement**
BDM/CDM/PDS dans lequel la fiche de raccordement au réseau d'alimentation fait partie intégrante de l'*enveloppe* de l'équipement, de sorte que l'équipement soit supporté par le socle de raccordement au réseau d'alimentation

[SOURCE: IEC 60050-903:2014, 903-04-07, modifié – "équipement" et “matériel” remplacés par "*BDM/CDM/PDS*".]

3.23
CTD As
classification de tension d'un circuit fournissant uniquement une tension de contact de sécurité, dans les conditions normales de fonctionnement et les *conditions de premier défaut*, ainsi que des surtensions limitées

Note 1 à l'article: Pour les limites, voir le Tableau 2.

[SOURCE: IEC 61204-7:2016, modifié – Définition reformulée.]

3.24
claquage électrique
défaillance de l'*isolation* en cas de contrainte électrique lorsque la décharge court-circuite complètement l'*isolation*, réduisant pratiquement à zéro la tension sur l'isolation

[SOURCE: IEC 60664-1:2020, 3.1.44, modifié – "entre les électrodes" remplacé par "sur l'*isolation*".]

3.25
isolation électrique
isolation
séparation électrique entre les circuits ou les parties conductrices assurée par la *distance d'isolement* et/ou la *ligne de fuite* et/ou l'*isolation solide*

Note 1 à l'article: Dans le présent document, "*distance d'isolement*" signifie "distance dans l'air".

3.26
écran de protection électrique
écran de protection
séparation de circuits par rapport aux *parties actives dangereuses* par un écran conducteur interposé relié au *conducteur de mise à la terre de protection*, directement ou par l'intermédiaire d'une *liaison équipotentielle de protection*

Note 1 à l'article: Si l'écran de protection est utilisé comme mesure de protection renforcée, voir 4.4.5.

3.27
protection électronique contre les surcharges du moteur
circuit de *BDM/CDM* qui protège un moteur dans des conditions de surcharge en réduisant le courant qui alimente le moteur

Note 1 à l'article: Le circuit de protection est généralement une combinaison de matériel et de logiciel.

Note 2 à l'article: Cette protection est habituellement réalisée au moyen d'un algorithme fondé sur le I^2t du courant du moteur.

3.28
protection contre les courts-circuits en sortie de puissance
circuit électronique
circuit interne de *BDM/CDM* qui réduit de manière significative la circulation du courant vers la sortie de puissance en cas de détection de conditions de court-circuit

Note 1 à l'article: Le circuit de protection est généralement une combinaison de matériel et de logiciel.

3.29
enveloppe
enceinte assurant le type et le degré de protection approprié pour l'application prévue

Note 1 à l'article: Le présent document fournit les exigences relatives à l'*enveloppe* conformément à l'IEC 60529, ainsi que les exigences supplémentaires relatives à l'impact mécanique et environnemental. Les exigences supplémentaires ont pour objet d'assurer que l'*enveloppe* fournit une *protection principale* dans les conditions environnementales spécifiées par le fabricant

[SOURCE: IEC 60050-151:2001, 151-13-08, modifié – Note 1 à l'article ajoutée.]

3.30
protection renforcée
mesure de protection dont la fiabilité n'est pas moindre que celle fournie par deux mesures de protection indépendantes au moyen d'une *isolation*, d'une distance ou d'une combinaison des deux

[SOURCE: IEC 61140:2016, 3.19, modifié – "mesure de protection" remplacé par "protection" dans le terme, et "au moyen d'une *isolation*, d'une distance ou d'une combinaison des deux" ajouté à la définition.]

3.31
durée de vie prévue
durée minimale pendant laquelle les caractéristiques des performances sont valides comme cela est spécifié par le fabricant

3.32
très basse tension
TBT
tension ne dépassant pas les limites de tension spécifiées dans l'IEC 61140:2016, Tableau 1

Note 1 à l'article: Dans l'IEC 61140, la *TBT* est définie comme ne dépassant pas la valeur efficace de 50 V en courant alternatif et de 120 V en courant continu. D'autres comités de produits peuvent avoir défini la *TBT* selon différents niveaux de tension.

Note 2 à l'article: Dans le présent document, la protection contre les chocs électriques dépend de la *classe de tension déterminante.*

3.33
protection en cas de défaut
protection contre les chocs électriques dans des *conditions de premier défaut*

Note 1 à l'article: Pour les *installations*, *systèmes* et équipements *basse tension*, la *protection en cas de défaut* de l'IEC 60364-4-41 correspond en général à la "protection contre les contacts indirects" précédemment utilisée, le plus souvent en ce qui concerne la défaillance de l'*isolation principale*.

[SOURCE: IEC 60050-195:2021, 195-06-02, modifié – Note à l'article ajoutée.]

3.34
borne pour câblage externe
borne prévue pour la connexion des conducteurs externes au *BDM/CDM/PDS*

Note 1 à l'article: Voir la Figure 7 et la Figure 8 pour des exemples de connexions de conducteurs internes et externes.

3.35
enveloppe ignifuge
partie d'un équipement destinée à réduire le plus possible l'extension du feu ou des flammes provenant de l'intérieur de l'*enveloppe* vers l'extérieur de l'*enveloppe*

3.36
isolation fonctionnelle
isolation entre les parties conductrices d'un circuit qui est nécessaire pour le bon fonctionnement du circuit, mais qui n'assure pas une protection contre les chocs électriques

Note 1 à l'article: L'*isolation fonctionnelle* peut cependant réduire la probabilité d'inflammation et de feu.

3.37
BDM/CDM/PDS portatif (à main)
BDM/CDM/PDS prévu pour être tenu à la main en usage normal

[SOURCE: IEC 60050-826:2004, 826-16-05, modifié – "matériel" remplacé par *"BDM/CDM/PDS"* dans le terme.]

3.38
zone d'accès général
zone du *BDM/CDM/PDS* à laquelle les *personnes ordinaires* et les *personnes qualifiées* sont autorisées à accéder

Note 1 à l'article: Les *zones d'accès général* n'exigent pas l'utilisation d'un outil ou d'une clé.

3.39
partie active dangereuse
partie active qui peut provoquer, dans certaines conditions, un choc électrique nuisible

Note 1 à l'article: Dans le présent document, une partie active dangereuse ne satisfait pas à l'exigence de *CTD As* du 4.4.2.2.

[SOURCE: IEC 60050-195:2021, 195-06-05, modifié – Traits d'union supprimés dans le terme et Note à l'article remplacée.]

3.40
BDM/CDM/PDS haute tension
BDM/CDM/PDS ayant une tension d'*accès* supérieure à 1 kV en courant alternatif, 50 Hz ou 60 Hz, ou supérieure à 1,5 kV en courant continu

Note 1 à l'article: "*Accès*" s'applique de façon générique à la fois à l'entrée et à la sortie, et le domaine d'application du présent document traite uniquement de la plage de tensions au niveau de l'*accès* d'entrée.

Note 2 à l'article: Voir l'IEC 61800-2:2021, Tableau 5.

Note 3 à l'article: Pour les *PDS* comportant des sections de convertisseur en série, une somme des tensions d'entrée entre phases connectées en série est utilisée comme tension d'entrée équivalente des sections de convertisseur (voir l'IEC 61800-2:2021, Annexe A).

Note 4 à l'article: Aux États-Unis d'Amérique, la plage de tensions de cette définition est considérée comme une tension moyenne.

[SOURCE: IEC 61800-2:2021, 3.16, modifié – "entre phases" ajouté à la Note 3 à l'article, "du domaine d'application du présent document" remplacé par "de cette définition" dans la Note 4 à l'article, et Note 5 à l'article supprimée.]

3.41
panneau articulé
partie d'une *enveloppe* composée de charnières, mais pas d'un *système* de verrouillage manuel, sécurisée en position fermée par plusieurs boulons ou d'autres matériels exigeant un outil autre qu'une clé pour fonctionner

Note 1 à l'article: Les *panneaux articulés* ne sont pas destinés à être ouverts dans les conditions normales de fonctionnement, le réglage de routine ou de simples opérations de maintenance (le remplacement de fusibles, par exemple).

3.42
installation
appareil ou ensemble de dispositifs ou d'appareils associés en vue d'une application déterminée et situés en un emplacement donné, y compris les moyens nécessaires à leur fonctionnement correct

Note 1 à l'article: Le mot "*installation*" est également utilisé dans le présent document pour désigner le processus d'installation d'un *PDS*. Dans ces cas, le mot n'apparaît pas en italique.

[SOURCE: IEC 60050-151:2001, 151-11-26, modifié – Note à l'article ajoutée.]

3.43
PDS intégré
PDS dont le moteur et les *BDM/CDM* sont mécaniquement intégrés dans un seul équipement

Note 1 à l'article: L'abréviation "PDS" est dérivée du terme anglais développé correspondant "*power drive system*".

[SOURCE: IEC 61800-2:2021, 3.28, modifié – "combinés" remplacé par "mécaniquement intégrés".]

3.44
verrouillage
dispositif(s) qui empêchent le fonctionnement d'un autre dispositif auquel ils sont directement associés dans des conditions particulières

Note 1 à l'article: Les *verrouillages* peuvent être électriques, mécaniques ou une combinaison des deux.

3.45
partie active
partie sous tension
partie conductrice destinée à être sous tension dans des conditions normales de fonctionnement, y compris le conducteur de neutre et le conducteur de point milieu, à l'exception toutefois du conducteur PEN, du conducteur PEM et du conducteur PEL

Note 1 à l'article: Cette notion n'implique pas nécessairement un risque de choc électrique.

Note 2 à l'article: Par convention, le conducteur PE n'est pas une partie active.

[SOURCE: IEC 60050-195:2021, 195-02-19, modifié – Notes à l'article ajoutées.]

3.46
basse tension
BT
ensemble des niveaux de tension utilisés pour la distribution d'énergie électrique et dont la limite supérieure généralement admise est de 1 000 V en courant alternatif ou 1 500 V en courant continu

[SOURCE: IEC 60050-601:1985, 601-01-26, modifié – "ou 1 500 V en courant continu" ajouté.]

3.47
BDM/CDM/PDS basse tension
BDM/CDM/PDS ayant une tension d'*accès* inférieure ou égale à 1 kV en courant alternatif, 50 Hz ou 60 Hz, ou 1,5 kV en courant continu

Note 1 à l'article: Pour les *PDS* comportant des sections de convertisseur en série, une somme des tensions d'entrée en série est utilisée comme tension d'entrée équivalente des sections de convertisseur (voir l'IEC 61800-2:2021, Annexe A).

[SOURCE: IEC 61800-2:2021, 3.30, modifié – Note 2 à l'article supprimée.]

3.48
réseau
système de distribution *basse tension* ou *haute tension* alimentant les *BDM/CDM/PDS*

3.49
valeur minimale exigée du courant de court-circuit présumé
$I_{\mathrm{cp,mr}}$
valeur efficace d'un *courant de court-circuit présumé minimal* devant provenir de la source afin d'assurer le fonctionnement du type spécifique de *dispositif de protection contre les courts-circuits*

[SOURCE: IEC 62477-1:2022, 3.38]

3.50
déplaçable
<*BDM/CDM/PDS*> équipement qui:

– pèse 18 kg ou moins et n'est pas fixé en place, ou
– est fourni avec des roues, des roulettes ou un autre moyen permettant de faciliter les mouvements qu'une *personne ordinaire* doit exécuter selon son utilisation prévue

[SOURCE: IEC 60050-903:2014, 903-04-06, modifié – "masse limitée" remplacé par "pèse 18 kg ou moins", et Note à l'article supprimée.]

3.51
alimentation non raccordée directement au réseau
source électrique qui n'est pas connectée directement au *réseau*

Note 1 à l'article: Les *alimentations non raccordées directement au réseau* sont, par exemple, isolées du *réseau* par un transformateur ou alimentées par une batterie, un générateur, des panneaux solaires, une éolienne, des systèmes marémoteurs, houlomoteurs, des piles à combustible ou des sources analogues qui ne sont pas connectées directement au réseau de distribution en courant alternatif ou en courant continu.

3.52
type ouvert
<*BDM/CDM*> destiné à être intégré dans une *enveloppe* ou une *zone d'accès limité* et qui assure la protection contre les dangers

Note 1 à l'article: Les dangers sont définis en 4.2.

3.53
personne ordinaire
personne qui n'est pas une *personne qualifiée*

EXEMPLE Un opérateur, une personne qui peut avoir accès à l'équipement ou une personne qui peut se trouver à proximité de l'équipement, lorsque ledit équipement n'est pas installé dans une *zone d'accès limité*.

[SOURCE: IEC 60050-826:2004, 826-18-03, modifié – "ni une personne avertie" supprimé, et exemple ajouté.]

3.54
courant de court-circuit en sortie
courant disponible qui circule au niveau de l'*accès* de sortie de puissance du *BDM/CDM* lorsqu'un court-circuit est appliqué par un conducteur d'impédance négligeable

3.55
surintensité
courant qui dépasse le courant assigné

Note 1 à l'article: Dans le présent document, le terme *surintensité* couvre à la fois le court-circuit et la surcharge.

3.56
circuit TBTP
schéma électrique dont la tension ne peut pas dépasser la valeur de la *très basse tension*:

– dans des conditions normales de fonctionnement; et
– dans des *conditions de premier défaut*, à l'exception des défauts à la terre dans les autres circuits électriques

Note 1 à l'article: *TBTP* est l'abréviation de *très basse tension de protection*.

[SOURCE: IEC 60050-826:2004, 826-12-32, modifié – "schéma" remplacé par "circuit" dans le terme, et "de fonctionnement" ajouté au premier tiret.]

3.57
équipement relié en permanence
équipement qui ne peut être connecté au réseau d'alimentation électrique ou en être déconnecté qu'à l'aide d'un outil

[SOURCE: IEC 60050-151:2014, 151-11-29]

3.58
équipement enfichable de type A
matériel du type A raccordé par prise de courant
équipement destiné à être raccordé au *réseau* ou à l'*alimentation non raccordée directement au réseau* par une fiche et un socle de prise de courant non industriels ou un connecteur non industriel ou les deux

Note 1 à l'article: Pour les fiches et socles de prise de courant non industriels, voir l'IEC TR 60083 ou un équivalent national. Pour les connecteurs non industriels, voir l'IEC 60320-1.

[SOURCE: IEC 60050-903:2014, 903-04-08, modifié – "*réseau d'alimentation*" remplacé par "*réseau* ou à l'*alimentation non raccordée directement au réseau*".]

3.59
équipement enfichable de type B
matériel du type B raccordé par prise de courant
équipement destiné à être raccordé au *réseau* ou à l'*alimentation non raccordée directement au réseau* par une fiche et un socle de prise de courant industriels ou un connecteur industriel ou par les deux

Note 1 à l'article: Pour les fiches et socles de prise de courant industriels, voir l'IEC 60309-1 ou un équivalent national. Pour les connecteurs non industriels, voir l'IEC 60320-1.

[SOURCE: IEC 60050-903:2014, 903-04-09, modifié – "*réseau d'alimentation*" remplacé par "*réseau* ou à l'*alimentation non raccordée directement au réseau*".]

3.60
accès
point d'un dispositif ou d'un réseau où de l'énergie électromagnétique ou des signaux électromagnétiques peuvent être fournis ou recueillis, ou bien où l'on peut observer ou mesurer des grandeurs

Note 1 à l'article: Dans le présent document, "entrée", "sortie", "puissance" et "commande" sont indiqués pour définir l'usage.

Note 2 à l'article: Pour l'évaluation de la sécurité, les accès couvrent également les interfaces comme cela est défini dans l'IEC 61800-1:2021, l'IEC 61800-2:2021 et l'IEC 61800-3:2017.

[SOURCE: IEC 60050-131:2002, 131-12-60, modifié – Note remplacée par la Note 1 à l'article et la Note 2 à l'article.]

3.61
entraînement électrique de puissance
PDS
système comprenant un ou plusieurs *modules d'entraînement complet (CDM)* avec un ou plusieurs moteurs

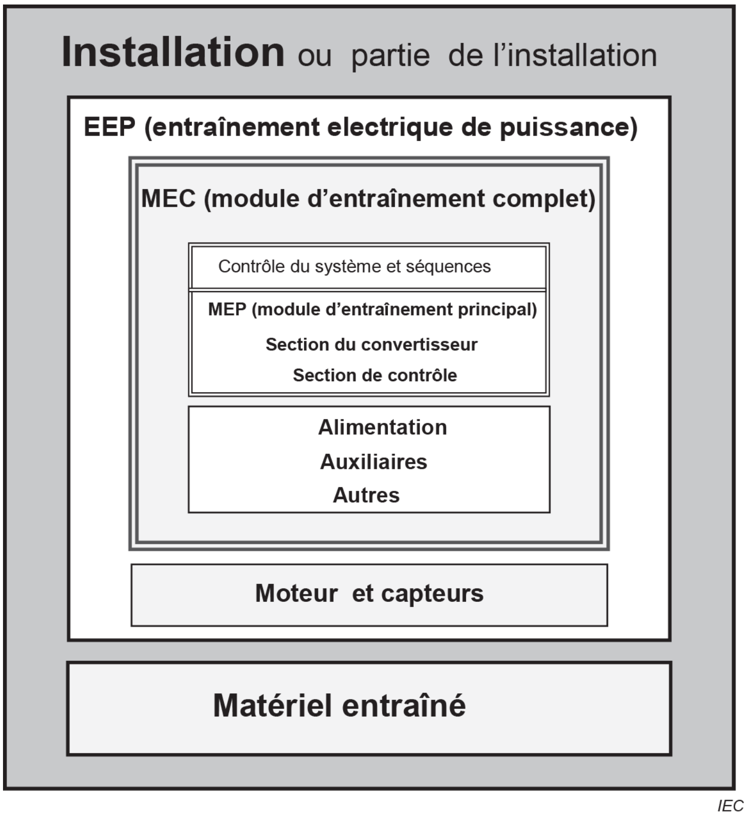


Figure 1 – Configuration matérielle d'un *PDS* dans une *installation*

Note 1 à l'article: Voir la Figure 1. Pour de plus amples informations, voir l'IEC 61800-2:2021, Figure 1.

Note 2 à l'article: Tous les capteurs, mécaniquement couplés à l'arbre du moteur qui font également partie du *PDS*; toutefois les matériels entraînés ne sont pas inclus.

Note 3 à l'article: L'abréviation "PDS" est dérivée du terme anglais développé correspondant "*power drive system*".

[SOURCE: IEC 61800-2:2021, 3.52, modifié – Note 1 à l'article ajoutée.]

3.62
courant de court-circuit présumé
I_{cp}
valeur efficace du courant symétrique qui circule lorsque les conducteurs d'alimentation du circuit sont court-circuités par un conducteur d'impédance négligeable placé aussi près que la pratique le permet des bornes d'alimentation des *BDM/CDM/PDS*

[SOURCE: IEC 61439-1:2020, 3.8.7, modifié – "courant" remplacé par "valeur efficace du courant symétrique", et "de l'ensemble" par "des *BDM/CDM/PDS*".]

3.63
liaison équipotentielle de protection
mise en œuvre de liaisons électriques entre parties conductrices pour réduire le plus possible toute différence de potentiel entre ces parties à des fins de sécurité

EXEMPLE La protection contre les chocs électriques.

3.64
protection de classe I
équipement dans lequel la protection contre les chocs électriques ne repose pas uniquement sur une *protection principale*, mais qui comprend une mesure de sécurité supplémentaire de telle manière que des moyens sont fournis pour la connexion des *parties accessibles* conductrices au *conducteur de mise à la terre de protection* dans le câblage fixe de l'*installation*, de sorte que les *parties accessibles conductrices* ne peuvent pas devenir actives en cas de défaut de l'*isolation principale*

Note 1 à l'article: La *protection de classe I* est définie dans l'IEC 61140:2016, 7.3.

3.65
protection de classe II
équipement dans lequel la protection contre les chocs électriques ne repose pas uniquement sur une *protection principale*, mais dans lequel des mesures de sécurité supplémentaires telles qu'une *isolation supplémentaire* ou une *isolation renforcée* sont fournies, sans aucun moyen de connexion à une *mise à la terre de protection* ni dépendance aux conditions d'*installation*

Note 1 à l'article: La *protection de classe II* est définie dans l'IEC 61140:2016, 7.4.

3.66
protection de classe III
équipement dans lequel la protection contre les chocs électriques repose sur une alimentation à CTD As (ou CTD *B* dans certaines conditions) et dans lequel des tensions supérieures à celles de CTD As (CTD *B)* ne sont pas générées et où il n'existe pas de moyen de connexion à une *mise à la terre de protection*

Note 1 à l'article: La *protection de classe II* est définie dans l'IEC 61140:2016, 7.5.

Note 2 à l'article: D'autres normes définissent la *protection de classe III* telle que fournie par la *très basse tension (TBT)*.

3.67
mise à la terre de protection
PE
mise à la terre d'un point dans un *système* ou d'un équipement à des fins de protection contre les chocs électriques en cas de défaut

Note 1 à l'article: L'abréviation "PE" est dérivée du terme anglais développé correspondant "*protective earthing*".

3.68
conducteur de mise à la terre de protection
conducteur dans l'*installation* électrique ou dans le câble d'alimentation, reliant une borne principale de mise à la terre de protection dans l'équipement à un point de mise à la terre dans l'*installation* à des fins de sécurité

Note 1 à l'article: Aux États-Unis et au Canada, le terme "Masse" et utilisé en lieu et place de "Terre".

3.69
impédance de protection
impédance connectée entre des *parties actives dangereuses* et des *parties accessibles* conductrices, de valeur telle que le courant, dans des conditions normales de fonctionnement et dans des *conditions de premier défaut*, soit limité à une valeur de sécurité, et qui est construite de façon telle que son aptitude soit maintenue au cours de la durée de vie de l'équipement

[SOURCE: IEC 60050-442:1998, 442-04-24, modifié – Définition reformulée.]

3.70
isolation renforcée
isolation des *parties actives dangereuses* assurant un degré de protection contre les chocs électriques équivalant à celui d'une *double isolation*

[SOURCE: IEC 60050-826:2004, 826-12-17, modifié – Note à l'article supprimée.]

3.71
zone d'accès limité
zone électrique sous enveloppe non destinée à l'entretien, à la maintenance ou à la mise en service pendant que le *BDM/CDM/PDS* est sous tension et à laquelle seules les *personnes qualifiées* sont autorisées à accéder

Note 1 à l'article: L'accès aux *zones d'accès limité* exige l'utilisation d'un outil ou d'une clé.

3.72
essai individuel de série
essai de conformité effectué sur chaque entité en cours ou en fin de fabrication

[SOURCE: IEC 60050-151:2001, 151-16-17]

3.73
essai sur prélèvement
essai effectué sur un certain nombre de dispositifs prélevés au hasard dans un lot

[SOURCE: IEC 61800-2:2021, 3.85]

3.74
circuit TBTS
schéma électrique dont la tension ne peut pas dépasser la valeur de la *très basse tension*:

– dans des conditions normales; et
– dans des *conditions de premier défaut*, y compris des défauts à la terre dans les autres circuits électriques

Note 1 à l'article: *TBTS est l'abréviation de très basse tension de sécurité*.

[SOURCE: IEC 60050-826:2004, 826-12-31, modifié – "schéma" remplacé par "circuit" dans le terme.]

3.75
zone d’accès pour la maintenance
zone électrique sous enveloppe destinée à l'entretien, à la maintenance et à la mise en service pendant que le *BDM/CDM/PDS* est sous tension et à laquelle seules les *personnes qualifiées* sont autorisées à accéder

Note 1 à l'article: L'accès aux *zones d'accès pour la maintenance* exige l'utilisation d'un outil ou d'une clé.

Note 2 à l'article: La *zone d'accès pour la maintenance* peut être un lieu dans lequel un bâtiment ou un espace à l'intérieur d'une *enveloppe*.

3.76
protection de secours contre les courts-circuits
protection destinée à fonctionner lorsque d’autres mesures de protection dans un *système* ou un matériel ne parviennent pas à éliminer un défaut

[SOURCE: IEC 62477-1:2022, 3.67]

3.77
dispositif de protection contre les courts-circuits
DPCC
dispositif destiné à protéger un circuit ou des parties d’un circuit contre les courants de court-circuit par l’interruption de ceux-ci

Note 1 à l'article: Un *dispositif de protection contre les courts-circuits* est uniquement adapté à la protection contre les courts-circuits, et non pas à la protection contre les surcharges. Un dispositif de protection contre les surintensités peut également intégrer la fonction d’un *DPCC*.

[SOURCE: IEC 61439-1:2020, 3.1.11, modifié – Note à l’article ajoutée.]

3.78
courant de courte durée admissible
I_{cw}
valeur efficace du courant de courte durée, déclarée par le fabricant du BDM/CDM/PDS, à laquelle le circuit peut résister dans les conditions spécifiées, définie en matière de courant et de temps

3.79
personne qualifiée
personne ayant la formation et l'expérience appropriées pour lui permettre de percevoir les risques et d'éviter les dangers que peut présenter l'équipement

[SOURCE: IEC 60050-826:2004, 826-18-01, modifié – "(en électricité)" supprimé du terme, et "l’électricité" remplacé par "l’équipement" dans le texte.]

3.80
condition de premier défaut
condition dans laquelle une défaillance est présente et peut provoquer un danger couvert par le présent document

Note 1 à l'article: Si une *condition de premier défaut* donne lieu à d'autres défaillances, l'ensemble de défaillances est considéré comme une *condition de premier défaut*.

Note 2 à l'article: Les dangers sont, par exemple, les chocs électriques, le feu, la pression énergétique, mécanique, le bruit acoustique, etc.

Note 3 à l'article: Le Guide IEC 116 donne des exemples de dangers.

3.81
isolation solide
matériau isolant solide, ou combinaison de matériaux isolants solides, placé entre deux parties conductrices ou entre une partie conductrice et une partie du corps

Note 1 à l'article: Dans le présent document, l'*isolation solide* ne couvre pas l'*isolation liquide*.

[SOURCE: IEC 60050-903:2015, 903-04-14, modifié – Exemple remplacé par une note à l'article.]

3.82
température de l'air ambiant environnant
<type ouvert> *température ambiante* maximale de l'air dans l'environnement immédiat de l'équipement de *type ouvert* à l'intérieur de la dernière *enveloppe*

3.83
environnement
toutes les parties du *BDM/CDM/PDS* adjacentes au circuit ou à la partie à l'étude

3.84
isolation supplémentaire
isolation indépendante prévue, en plus de l'isolation principale, en tant que protection en cas de défaut

Note 1 à l'article: *L'isolation principale* et *l'isolation supplémentaire* sont séparées, chacune étant conçue pour une *protection principale* contre les chocs électriques.

[SOURCE: IEC 60664-1:2020, 3.1.31, modifié – Note à l'article ajoutée.]

3.85
dispositif de protection contre les surtensions
parafoudre
SPD
dispositif incluant au moins un *composant* non linéaire destiné à limiter les surtensions et à écouler les courants de foudre

Note 1 à l'article: Un parafoudre (SPD) est un ensemble complet disposant de moyens de connexion appropriés.

Note 2 à l'article: L'abréviation "SPD" est dérivée du terme anglais développé correspondant "*surge protective device*".

[SOURCE: IEC 61643-11:2011, 3.1.1, modifié – en français, ajout de la Note 2 à l'article]

3.86
système
ensemble d'éléments indépendants corrélés et/ou interconnectés

Note 1 à l'article: Un *système* est généralement défini en fonction de son objectif précis, par exemple la réalisation d'une fonction définie telle que la mise à la terre des *systèmes*, *systèmes* de câblage, *systèmes* d'alimentation et *systèmes d'isolation*.

3.87
tension système
tension utilisée pour déterminer les exigences de l'*isolation*

Note 1 à l'article: Voir 4.4.7.1.7 pour des informations supplémentaires sur la *tension système*.

3.88
surtension temporaire
surtension à fréquence industrielle de durée relativement longue

[SOURCE: IEC 60664-1:2020, 3.1.12]

3.89
mémoire thermique
capacité d'un *système* de protection contre les surcharges à réduire l'échauffement et le refroidissement d'un moteur protégé pendant son fonctionnement

3.90
rétention de mémoire thermique
capacité à retenir une représentation de l'état thermique d'un moteur avant son déclenchement ou sa perte de puissance

Note 1 à l'article: La rétention de mémoire thermique sert généralement au *système* de protection contre les surcharges à régler la température du moteur au redémarrage.

Note 2 à l'article: La rétention de mémoire thermique peut inclure une réduction continue de la représentation thermique afin de refléter le refroidissement du moteur lors de son déclenchement ou sa perte de puissance.

3.91
courant de contact
courant électrique passant dans le corps humain ou dans celui d'un animal lorsqu'il est en contact avec une ou plusieurs *parties accessibles* conductrices d'une installation électrique ou de matériels électrique

[SOURCE: IEC 60050-826:2004, 826-11-12, modifié – "conductrices" ajouté.]

3.92
déclenchement
lancement d'une réduction ou d'une élimination rapide et commandée du transfert d'énergie à tout dispositif ou processus initié par un défaut détecté ou une *condition anormale de fonctionnement*

3.93
essai de type
essai de conformité effectué sur un ou plusieurs *BDM/CDM/PDS* représentatifs de la production

[SOURCE: IEC 60050-151:2001, 151-16-16, modifié – "entités" remplacé par "*BDM/CDM/PDS".*]

3.94
inspection visuelle
examen minutieux d'une entité, effectué sans désassemblage, ou avec un désassemblage partiel si exigé, afin d'aboutir à une conclusion fiable sur l'état de l'entité

[SOURCE: IEC 60050-426:2020, 426-14-02, modifié – Définition reformulée.]

3.95
tension de fonctionnement
tension qui apparaît par conception dans un circuit ou au travers d'une *isolation*, dans les conditions assignées d'alimentation (sans tolérances) et dans les conditions de fonctionnement les plus défavorables

Note 1 à l'article: La *tension de fonctionnement* peut être en courant continu ou en courant alternatif. Les valeurs de crêtes répétitives et les valeurs efficaces sont utilisées.

3.96
zone de liaison équipotentielle
zone où toutes les *parties accessibles* conductrices simultanément sont connectées électriquement pour empêcher l’apparition de tensions dangereuses entre elles

4 Protection contre les dangers

4.1 Généralités

L'Article 4 définit les exigences minimales pour la conception et la réalisation d’un *BDM/CDM/PDS* et des *accessoires* pour l'utilisation prévue, afin d'assurer sa sécurité pendant l’installation, les conditions normales de fonctionnement et la maintenance pour la *durée de vie prévue* du *BDM/CDM/PDS*. La réduction des dangers résultant d’une mauvaise utilisation raisonnablement prévisible est également prise en considération.

La protection contre les dangers doit être maintenue dans des conditions normales de fonctionnement, dans des *conditions anormales de fonctionnement* et dans les *conditions de premier défaut,* comme cela est spécifié dans le présent document.

Si le *PDS* est destiné à être utilisé avec un équipement ou des *accessoires* particuliers, l'évaluation et les essais de sécurité doivent inclure cette information, sauf s'il peut être démontré que cela n'a aucun impact sur la sécurité du *PDS* ou de l'équipement particulier.

Des recommandations relatives à l’appréciation du risque des équipements et systèmes électriques sont fournies dans le Guide IEC 116, qui a été adapté aux *BDM/CDM/PDS* dans l’Annex R.

4.2 *Conditions de premier défaut* et *conditions anormales de fonctionnement*

Le *BDM/CDM/PDS* et les *accessoires* doivent être conçus de façon à éviter les modes ou les séquences de fonctionnement susceptibles de provoquer une *condition de premier défaut* ou une défaillance de *composant* conduisant à un danger, à moins que d’autres mesures ne soient fournies par l’*installation* pour empêcher ce danger et ne soient décrites dans les informations d'installation qui accompagnent le *BDM/CDM/PDS* (voir Article 6). Les exigences du 4.2 s'appliquent également aux *conditions anormales de fonctionnement*, selon le cas.

Une analyse des circuits doit être réalisée afin d’identifier des dangers potentiels.

L'analyse des circuits doivent inclure les situations dans lesquelles la défaillance de tout *composant*, système d’*isolation* ou *accès* engendre

- un risque de force électromagnétique et des dangers thermiques selon 4.3,
- un impact sur la détermination de la tension déterminante selon 4.4.2,
- un risque de choc électrique dû
  - à la dégradation de la *protection principale* selon 4.4.3, ou
  - à la dégradation de la *protection en cas de défaut* selon 4.4.4,
- un risque de danger dû à l'énergie selon 4.5,
- un risque de dégradation due à l'émission de flamme, de particules brûlantes ou de métal fondu selon 4.6,
- un risque de danger thermique dû à une température élevée selon 4.6, et
- un risque de danger mécanique selon 4.7.

NOTE Le présent document ne formule aucune exigence de protection contre les dangers chimiques.

L'analyse de circuit doit inclure les effets des conditions de court-circuit et de circuit ouvert. Les essais sont nécessaires, sauf si l'analyse de circuit permet de conclure qu'aucun danger ne résulte d'une défaillance. Si les essais sont exigés, la conformité doit être vérifiée par l'essai de 5.2.4.10.

Outre cette analyse, les *composants* doivent satisfaire aux exigences de 4.13.

Les *distances d'isolement*, les *lignes de fuite* et les matériaux *isolants solides* conçus pour une *protection renforcée* (voir 4.4.5) selon 4.4.7.4, 4.4.7.5 et 4.4.7.8 sont considérés comme satisfaisant à ces exigences et ne nécessitent pas un examen plus approfondi.

L'*isolation fonctionnelle* sur les cartes de circuit imprimé entre les parties des *composants* assemblés sur les cartes de circuit imprimé ne satisfaisant pas aux exigences de *distance d'isolement* et de *ligne de fuite* du 4.4.7.4 et du 4.4.7.5 doit satisfaire aux exigences du 4.4.7.7.

Les dangers potentiels concernant la sécurité associés aux *composants* essentiels du *PDS*, tels que les pièces pivotantes du moteur et l'inflammabilité des huiles des transformateurs et condensateurs, doivent être examinés.

L'analyse doit inclure les circuits à source de puissance limitée, uniquement si une défaillance du *composant* du circuit à source de puissance limitée crée un danger dans un circuit qui n'est pas alimenté par un circuit à source de puissance limitée.

L'analyse doit également inclure un autre examen, étude, analyse, calcul ou essai exigé pour tenir compte des dangers non électriques. Les essais sont nécessaires, sauf si l'analyse démontre qu'aucun danger ne résulte de la défaillance des *composants* et des parties mécaniques.

4.3 Protection contre les courts-circuits et les surcharges

4.3.1 Généralités

Pour satisfaire aux exigences définies en 4.2, le *BDM/CDM/PDS* ne doit présenter aucun danger dans les conditions de court-circuit ou de surcharge (appelés défaut), quel que soit l'*accès* de puissance, y compris entre phases, phase/terre et phase/neutre. Des informations appropriées doivent être fournies dans la documentation pour permettre une sélection appropriée du câblage de l'*installation* et des dispositifs de protection externes du *BDM/CDM/PDS*.

Si un système de protection ou un dispositif de protection est exigé pour la protection contre les courts-circuits et les surcharges, ces moyens doivent être fournis ou spécifiés.

Pour le marquage, voir 6.3.9.6.

NOTE 1 Les codes d'*installation* locaux exigent en général de prévoir ce type de protection pour protéger le câblage d'entrée dans l'*installation.* Dans certains cas, il est possible que les codes d'*installation* locaux remplacent les exigences du présent document.

La protection contre les *surintensités* doit être prévue pour tous les *accès*, sauf

- les *accès* qui satisfont aux exigences des sources de puissance limitée du 4.5.3, ou
- si le *BDM/CDM/PDS* satisfait à toutes les conditions normales de fonctionnement, *conditions anormales de fonctionnement* et *conditions de premier défaut* du présent document en l'absence de ce type de protection.

NOTE 2 Dans le présent document, le terme *surintensité* couvre à la fois les courts-circuits et les surcharges.

Si la protection contre les *surintensités* est exigée, elle peut être intégrée au *BDM/CDM/PDS* ou peut être prévue dans l'*installation*, et les détails relatifs au dispositif de protection contre les *surintensités* exigé doivent être fournis dans les instructions d'installation du *BDM/CDM/PDS* selon 6.3.9.6.

Aucune protection n'est exigée contre les *surintensités* à la terre sur les *accès*

- ne comportant aucune connexion à la terre, ou
- comportant une *protection renforcée* entre les *parties actives* et toutes les parties conductrices reliées à la terre.

NOTE 3 Si la *protection renforcée* est fournie, un court-circuit à la terre est considéré comme deux défauts.

Les essais ne sont pas exigés en cas de *condition de premier défaut* à la terre dans le *BDM/CDM/PDS* installé dans un *système* informatique.

NOTE 4 En cas de *condition de premier défaut* dans un *système* informatique, aucun courant de court-circuit ou courant de court-circuit limité ne circule. Un courant de court-circuit circule dans un *système* informatique en cas de second défaut. En règle générale, seule une détection a lieu après le premier défaut dans un *système* informatique.

Pour les *équipements enfichables de type A*, le dispositif de protection est prévu dans l'*installation* et ne doit pas exiger de caractéristiques spécifiques autres que celles exigées dans l'IEC 60364 (toutes les parties) ou d'autres codes d'*installation* locaux.

Pour les *équipements enfichables de type B* ou les *BDM/CDM/PDS connectés en permanence*, cette protection peut être assurée par des dispositifs externes au *BDM/CDM/PDS*, auquel cas les instructions d'installation doivent indiquer la nécessité de protection dans l'*installation* et doivent inclure les spécifications en matière de protection contre les courts-circuits et/ou les surcharges (voir 6.3.9.6).

NOTE 5 L'IEC 60364 (toutes les parties) fournit les exigences en matière de protection contre les courts-circuits et les surcharges du câblage d'entrée dans l'*installation.* Les exigences ci-dessus assurent que l'utilisateur est informé de toutes les caractéristiques particulières des dispositifs de protection du *PDS*, en plus des exigences de l'IEC 60364 (toutes les parties) ou d'autres codes d'*installation* locaux.

Si un dispositif de protection interrompt le conducteur de neutre, il doit également interrompre simultanément tous les autres conducteurs d'alimentation du même circuit. Le dispositif de protection peut interrompre le conducteur de neutre après les autres conducteurs d'alimentation du même circuit.

Il faut prendre en considération la conformité

- aux différents types de systèmes de mise à la terre (TN, TT, IT, en étoile ou "corner-earthed" du 4.4.7.1.5) dans la mesure où le courant de court-circuit vers la mise à la terre de protection dépend du type système de mise à la terre,
- à la déconnexion automatique de l'alimentation du 4.4.4.4.1,
- au temps de déconnexion du 4.4.4.4.2 tel qu'exigé dans l'IEC 60364-4-41:2005 et l'IEC 60364-4-41:2005/AMD1:2017, 411.3.2, (voir l'Annex Q), et
- à l'alternative à la déconnexion automatique de l'alimentation du 4.4.4.4.3.

NOTE 6 L'IEC 60364-4-41:2005 et IEC 60364-4-41:2005/AMD1:2017, 411.3.2 fournissent plus d'informations sur la protection contre les contacts indirects dans le cas d'un court-circuit entre les *parties actives dangereuses* et la mise à terre de protection.

NOTE 7 Le courant de défaut de court-circuit vers la terre est prévu pour être inférieur ou égal au courant de court-circuit assigné de l'*accès* de puissance de sortie en fonction du type de système de mise à la terre.

4.3.2 Valeurs assignées de court-circuit en entrée et *courant* disponible *de court-circuit en sortie*

4.3.2.1 Généralités

La capacité d'interruption du dispositif de protection contre les *surintensités* doit être supérieure ou égale au *courant de court-circuit présumé* du *réseau ou de l'alimentation non raccordée directement au réseau*.

Pour les *équipements enfichables de type A*, soit le *PDS* doit être conçu de sorte que l'*installation* assure une *protection de secours contre les courts-circuits*, soit une *protection de secours contre les courts-circuits* supplémentaire doit être prévue comme partie intégrante du *BDM/CDM/PDS*.

Pour les *équipements enfichables de type B* ou les *BDM/CDM/PDS connectés en permanence*, il est admis de prévoir une *protection de secours contre les courts-circuits* dans l'*installation*.

4.3.2.2 Courant conditionnel assigné de court-circuit (I_{cc}) sur les *accès* de puissance d'entrée

Les caractéristiques assignées de *courant de court-circuit présumé* en entrée s'appliquent aux *accès* destinés à être reliés au *réseau ou à l'alimentation non raccordée directement au réseau* en courant alternatif ou en courant continu et à d'autres *accès* pour lesquels la protection contre les *surintensités* est nécessaire.

Le fabricant de *BDM/CDM/PDS* doit spécifier un *courant conditionnel de court-circuit* (I_{cc}) pour la conformité à 4.3.2.2, et, de plus, les informations de a) ou b):

a) Informations relatives au *dispositif de protection contre les courts-circuits*:
   - le courant de *court-circuit prospectif* minimal requis ($I_{cp,mr}$); et
     1) la tension, le courant, le pouvoir de coupure, I_p et I^2t nominaux du dispositif de protection à I_{cc}; ou
     2) le fabricant du dispositif de protection et son numéro de référence;

b) Informations relatives au *dispositif de protection contre les courts-circuits*:
   - la durée associée, et
   - si un dispositif de protection spécifique est utilisé pour satisfaire à cette exigence, le fabricant doit spécifier le fabricant ainsi que le numéro de produit du dispositif de protection.

La durée associée de b) est la durée pendant laquelle le *courant de court-circuit présumé* symétrique maximal a été appliqué pendant l'essai du 5.2.4.4, du 5.2.4.5 et du 5.2.4.10.

La conformité est indiquée par une évaluation conforme à 4.2 afin de déterminer la combinaison d'essais appropriée selon 5.2.4.4, 5.2.4.5 et 5.2.4.10 et d'évaluer les *conditions anormales de fonctionnement* et la *condition de premier défaut*, y compris les défauts d'*isolation*.

Pour les topologies dans lesquelles le *BDM/CDM* comprend un transformateur d'entrée, il convient de porter une attention particulière au fait que le courant de défaut est considérablement supérieur du côté primaire du transformateur. Cela s'applique particulièrement aux topologies à haute tension. Voir l'IEC 61800-2:2021, Annexe A.

Si l'analyse indique que le résultat d'un essai est représentatif du cas le plus défavorable, il n'est pas nécessaire de soumettre à l'essai des combinaisons moins sévères.

Pour le marquage, voir 6.2.1.4 g).

4.3.2.3 *Courant* disponible *de court-circuit* en sortie

Les caractéristiques assignées de *courant* disponible *de court-circuit* en sortie s'appliquent à chaque *accès* de sortie dont la protection contre les *surintensités* doit être choisie entre la sortie d'un *BDM/CDM* et l'entrée d'un autre *BDM/CDM*.

Pour chaque *accès* de sortie, l'évaluation du court-circuit pour déterminer le *courant* disponible *de court-circuit en sortie* maximal doit être réalisée selon 5.2.4.5.

Pour le marquage, voir 6.2.1.4 g).

4.3.2.4 *Accès* d'entrée et de sortie combinés

Pour les *accès* qui sont à la fois des *accès* d'entrée et de sortie, les exigences applicables du 4.3.2.2 et du 4.3.2.3 s'appliquent.

4.3.3 Coordination de court-circuit (protection en amont)

Les dispositifs de protection fournis ou spécifiés doivent présenter une aptitude adéquate à l'interruption du *courant de court-circuit présumé* spécifié pour l'*accès* auquel ils sont connectés.

Si la protection interne du *BDM/CDM/PDS* n'est pas adaptée au *courant de court-circuit présumé*, les instructions d'installation doivent spécifier le dispositif de protection en amont, adapté au *courant de court-circuit présumé* sur cet *accès*, qui doit être utilisé pour assurer la protection (voir 6.3.9.6). La combinaison de ces deux dispositifs de protection contre les *surintensités* doit être spécifiée par le fabricant des dispositifs de protection comme étant adaptée à une utilisation en combinaison pour la protection d'un circuit dont le *courant de court-circuit présumé* ne dépasse pas les caractéristiques assignées du dispositif de protection en amont.

NOTE L'IEC 60364 (toutes les parties) donne les exigences relatives aux dispositifs de protection en amont dans l'*installation.* Les exigences ci-dessus assurent que l'utilisateur est informé de toutes les caractéristiques particulières des dispositifs de protection en amont du *PDS*, en plus des exigences de l'IEC 60364 (toutes les parties) ou d'autres codes d'*installation* locaux.

La conformité doit être vérifiée par l'*inspection visuelle* du 5.2.1 et par les essais du 5.2.4.5.

4.3.4 Protection par plusieurs dispositifs

Si des dispositifs de protection exigeant un remplacement manuel ou un nouveau réglage sont utilisés en plusieurs endroits d'une alimentation à une charge donnée, ces dispositifs doivent être placés ensemble, sauf en cas de conflits avec une autre considération de conception fondée sur la sécurité.

NOTE La ségrégation de phase visant à éviter ou réduire les défauts d'arc est une éventuelle raison qui explique pourquoi les dispositifs de protection peuvent ne pas être placés ensemble.

Il est admis de combiner au moins deux dispositifs de protection dans un *composant*.

L'emplacement des dispositifs de protection doit être défini dans la documentation (voir 6.2).

La conformité doit être vérifiée par l'*inspection visuelle* du 5.2.1.

4.3.5 Protection contre la surchauffe et contre les surcharges du moteur

4.3.5.1 Moyens de protection

Un moteur de *PDS* doit être protégé contre la surchauffe. Suivant l'application du moteur, un ou plusieurs moyens de protection doivent être choisis par le fabricant du *PDS* parmi les suivants a), b), c), d) ou e) pour chaque moteur:

a) un relais de surcharge thermique ou électronique conforme aux exigences applicables de l'IEC 60947-4-1:2018;

b) un *BDM/CDM* avec une *protection électronique contre les surcharges du moteur* conformément à 4.3.5.2, qui peut inclure

   1) une *rétention de mémoire thermique* selon 4.3.5.3, et/ou

   2) une sensibilité de vitesse selon 4.3.5.4;

c) un BDM/CDM avec une surveillance et un *déclenchement* fondés sur un signal provenant d'un capteur thermique monté dans ou sur le moteur conformément à 4.3.5.5;

d) une protection thermique intégrée au moteur qui déconnecte le moteur;

e) des informations conformément à 6.3.9.7.1.

NOTE 1 Les choix a) et d) sont les seules protections contre les surcharges du moteur dans le cas de plusieurs moteurs en parallèle alimentés par le même *accès* de puissance de moteur de *BDM/CDM*.

Pour les exigences d'informations, voir 6.3.9.7 et 6.3.10.2.

NOTE 2 Aux États-Unis, conformité au National Electrical Code ANSI/NFPA 70 pour:

– la protection contre les surcharges conformément à 430.32 est assurée selon a), b), c) ou d); et

– la protection contre la surchauffe conformément à 430.126 est assurée selon b) 1) et b) 2), c) ou d).

4.3.5.2 *BDM/CDM* avec *protection électronique contre les surcharges du moteur*

La *protection électronique contre les surcharges du moteur* doit être conforme aux 5.2.4.6.1 à 5.2.4.6.4 et est soumise aux exigences d'essai du 5.2.4.7.

Une *protection électronique contre les surcharges du moteur* réglable ne doit pas être réglable de telle sorte que les limites du Tableau 37 soient dépassées.

a) Pour le *PDS* où le moteur et le *BDM/CDM* sont connus, d'autres limites que celles du Tableau 37 peuvent être spécifiées et soumises à l'essai conformément aux 5.2.4.6.1 à 5.2.4.6.4.

b) Pour les exigences d'informations, voir 6.3.9.7.2.

4.3.5.3 *BDM/CDM* avec *protection électronique contre les surcharges du moteur* avec *rétention de mémoire thermique*

Une *protection électronique contre les surcharges du moteur* avec *rétention de mémoire thermique* doit être conforme aux 5.2.4.6.1 à 5.2.4.6.6 et est soumise aux exigences du 5.2.4.7.

4.3.5.4 BDM/CDM avec *protection électronique contre les surcharges du moteur* qui est sensible à la vitesse

La *protection électronique contre les surcharges du moteur* qui est sensible à la vitesse doit être conforme aux 5.2.4.6.1 à 5.2.4.6.7 et est soumise aux exigences du 5.2.4.7.

EXEMPLE Les moteurs à induction avec ventilateur monté sur l'arbre.

4.3.5.5 *BDM/CDM* assurant une surveillance et un *déclenchement* au moyen de capteurs thermiques

Les *BDM/CDM* conçus pour être utilisés avec des moteurs comportant une protection thermique ou un capteur thermique dans ou sur les moteurs exigeant une *interface* de signaux doivent être fournis avec les moyens de se connecter à cette protection.

Les exigences d'*isolation* pour la connexion du protecteur ou du capteur thermique doivent être prises en considération. Voir le Tableau 3.

Pour le marquage, voir 6.3.10.2.

4.3.6 *BDM/CDM* fournissant une commande à limitation de courant

Un *BDM/CDM* intégrant une commande de limitation de courant, c'est-à-dire un circuit qui limite le courant de sortie à une valeur définie, quelle que soit la charge sur le moteur, doit être soumis à l'essai selon 5.2.4.8.

NOTE La commande de limitation de courant peut être une valeur fixe ou réglable par l'opérateur.

4.4 Protection contre les chocs électriques

4.4.1 Généralités

La protection contre les chocs électriques dépend de la *classe de tension déterminante (CTD*) du 4.4.2 et des exigences de protection du Tableau 3 et doit être assurée par au moins l'une des mesures suivantes a) ou b):

a) *protection principale* du 4.4.3 et *protection en cas de défaut* du 4.4.4; ou
b) *protection renforcée* du 4.4.5.

La protection dans les conditions normales de fonctionnement est assurée par la *protection principale* 4.4.3, la protection dans les *conditions de premier défaut* étant assurée par la *protection en cas de défaut* 4.4.4.

La *protection renforcée* (voir 4.4.5) assure la protection à la fois dans des conditions normales de fonctionnement et dans des *conditions de premier défaut*.

La *protection principale*, la *protection en cas de défaut* et la *protection renforcée* peuvent être obtenues au moyen des *distances d'isolement* et des *lignes de fuite* (voir 4.4.7.4 et 4.4.7.5), de l'*isolation solide* (voir 4.4.7.8) ou de la protection au moyen d'une *enveloppe* et de barrières (voir 4.4.3.3) ou d'une combinaison de ces éléments.

L'Article A.6 donne un aperçu du concept fondamental de protection contre les chocs électriques dans le présent document.

NOTE Dans le présent document, 4.4.1 à 4.4.6 ont été harmonisés avec les concepts de la norme horizontale IEC 61140 concernant la protection contre les chocs électriques. La *protection principale*, la *protection en cas de défaut*, la *protection renforcée* et une combinaison de ces mesures ont été mises en œuvre.

Une protection supplémentaire peut être assurée par des dispositifs de protection à courant différentiel résiduel (DDR). Pour plus d'informations, voir 4.4.8.

4.4.2 *Classe de tension déterminante (CTD)*

4.4.2.1 Généralités

Le présent document définit quatre niveaux de tension présentant différentes exigences en matière de protection contre les chocs électriques, *CTD As*, *CTD B*, *CTD C* et *CTD D*.

La détermination d'une *classe de tension déterminante* inclut les considérations suivantes:

a) environnement intérieur sans condition ou extérieur sans condition du Tableau 20;
b) conditions normales de fonctionnement, *conditions anormales de fonctionnement* et *conditions de premier défaut*;
c) valeur efficace V_{ac} de la *tension de fonctionnement* maximale, V_{ac} crête et V_{dc} du Tableau 2, de la Figure 2, de la Figure 3 et de la Figure 4;
d) exigences de protection entre les circuits et entre les circuits et l'*environnement* du 4.4.2.7 ou du Tableau 3;
e) *tension de tenue aux chocs* du Tableau 2, du Tableau 6 ou du Tableau 7 pour toutes les *CTD.*

De plus amples informations relatives à l'évaluation de la *tension de fonctionnement* sont fournies à l'Article A.5.

4.4.2.2 *CTD As*

Un circuit *CTD As* est défini comme étant sûr au contact dans les conditions de fonctionnement normal, les *conditions anormales de fonctionnement* et les *conditions de premier défaut* (voir le Tableau 2).

La *CTD As* doit satisfaire à toutes les exigences minimales a), b) et c) du 4.4.2.2:

a) tension ne dépassant pas la *tension de fonctionnement* maximale en régime permanent selon le Tableau 2;
b) séparation des autres circuits selon 4.4.2.7 ou le Tableau 3;
c) tension de courte durée maximale dans des *conditions anormales de fonctionnement* et dans des *conditions de premier défaut* selon le Tableau 2, la Figure 2, la Figure 3 et la Figure 4.

Un circuit qui ne satisfait pas à toutes les exigences minimales a), b) et c) du 4.4.2.2 doit être considéré soit comme un circuit *CTD B,* soit comme un circuit *CTD C*, soit comme un circuit *CTD D*, puis doit être évalué pour déterminer s'il satisfait aux exigences *CTD B* selon 4.4.2.3.

Les circuits destinés à être connectés à des dispositifs externes au *BDM/CDM/PDS,* dont le niveau de tension se trouve dans les limites de la *CTD As,* doivent satisfaire aux exigences minimales a), b) et c) du 4.4.2.2.

Voir également 4.4.6.5.3.

Pour le marquage, voir 6.2.1.

4.4.2.3 *CTD B*

Un circuit *CTD B* est nécessaire si le circuit est une *interface* avec les circuits *TBTS* ou *TBTP*, lorsque la tension nominale ou la tension de courte durée maximale dans des *conditions anormales de fonctionnement* et dans des *conditions de premier défaut* dépasse les limites de tension *CTD As*.

NOTE La tension *CTD B* maximale est maintenue dans les limites TBT comme cela est défini dans l'IEC 61140 (identiques à *TBTS* et *TBTP*) dans les conditions normale et les *conditions de premier défaut* (voir le Tableau 2).

La *CTD B* doit satisfaire à toutes les exigences a), b) et c) du 4.4.2.3:

a) tension ne dépassant pas la *tension de fonctionnement* maximale en régime permanent selon le Tableau 2;

b) séparation des autres circuits selon 4.4.2.7 ou le Tableau 3;

c) tension de courte durée maximale dans des *conditions anormales de fonctionnement* et dans des *conditions de premier défaut* selon le Tableau 2, la Figure 2, la Figure 3 et la Figure 4.

Un circuit qui ne satisfait pas à toutes les exigences minimales a), b) et c) du 4.4.2.3 doit être considéré soit comme un circuit *CTD C*, soit comme un circuit *CTD D*, puis doit être évalué pour déterminer s'il satisfait aux exigences *CTD C* selon 4.4.2.4.

4.4.2.4 *CTD C*

Les circuits *CTD C* présentent des tensions dangereuses et exigent une *protection principale* et une *protection en cas de défaut* ou une *protection renforcée* dans les zones sèches, mouillées et mouillées à l'eau salée pour la protection contre les chocs électriques.

La *CTD C* doit satisfaire à toutes les exigences a), b) et c) du 4.4.2.4:

a) tension ne dépassant pas la *tension de fonctionnement* maximale en régime permanent selon le Tableau 2;

b) séparation des autres circuits selon 4.4.2.7 ou le Tableau 3;

c) une *tension de tenue aux chocs* maximale et une *surtension temporaire*, le cas échéant, selon 4.4.7.1 à 4.4.7.4.

Les exigences de séparation des autres circuits *CTD C* doivent s'appuyer sur les conséquences d'une *condition de premier défaut* (voir 4.2) dans l'*isolation* et peuvent être une *protection renforcée*, une *protection principale* ou une *isolation fonctionnelle*, et doivent reposer sur la *tension de fonctionnement* et la *tension de tenue aux chocs* maximales.

Un circuit qui ne satisfait pas à toutes les exigences minimales a), b) et c) du 4.4.2.4 doit être considéré soit comme un circuit *CTD D*, puis doit être évalué pour déterminer s'il satisfait aux exigences *CTD D* selon 4.4.2.5.

4.4.2.5 *CTD D*

Les circuits *CTD D* présentent des tensions dangereuses pour les *BDM/CDM/PDS haute tension* et exigent une *protection principale* et une *protection en cas de défaut* ou une *protection renforcée* dans les zones sèches, mouillées et mouillées à l'eau salée pour la protection contre les chocs électriques.

Les circuits *CTD D* ne sont pas classés *CTD As, CTD B* ou *CTD C* et doivent satisfaire à toutes les exigences a) et b) du 4.4.2.5:

a) séparation des autres circuits selon 4.4.2.7 ou le Tableau 3;

b) une *tension de tenue aux chocs* maximale et une *surtension temporaire*, selon 4.4.7.1 à 4.4.7.4, le cas échéant.

Les exigences de séparation des autres circuits *CTD D* doivent s'appuyer sur les conséquences d'une *condition de premier défaut* (voir 4.2) dans l'*isolation* et peuvent être une *protection renforcée*, une *protection principale* ou une *isolation fonctionnelle*, et doivent reposer sur la *tension de fonctionnement* et la *tension de tenue aux chocs* maximales.

Pour le marquage, voir 6.5.7.

4.4.2.6 Détermination de la *classe de tension déterminante (CTD)*

4.4.2.6.1 Généralités

Les mesures de protection contre les chocs électriques dépendent de la *CTD* des circuits selon 4.4.2.2 à 4.4.2.5. La *CTD*, quant à elle, détermine le niveau minimal de protection exigé pour le circuit.

4.4.2.6.2 Limites de *tension de fonctionnement* pour la *CTD*

Les limites de *tension de fonctionnement* selon la *CTD* pour les conditions normales de fonctionnement, les *conditions anormales de fonctionnement* et les *conditions de premier défaut* sont données dans le Tableau 2.

Tableau 2 – Limites de tension pour les *classes de tension déterminantes*

<table>
<tr><th rowspan="2"></th><th colspan="6">Limites de la tension de fonctionnement</th></tr>
<tr><th colspan="4">Dans des conditions normales de fonctionnement
V</th><th colspan="2">Dans des conditions de premier défaut et dans des conditions anormales de fonctionnement
V</th></tr>
<tr><th>CTD</th><th>Tension continue (valeur efficace)
U_{acl}</th><th>Tension alternative (valeur de crête)
U_{acpl}</th><th>Tension continue (moyenne)
U_{dcl}</th><th>Tension de tenue aux chocs</th><th>Tension
(crête en courant alternatif ou courant continu) 10 ms à 200ms</th><th>Tension
(crête en courant alternatif ou courant continu)
entre 200 ms et 1 000 ms</th></tr>
<tr><td>As
(mouillé à l'eau salée) [e]</td><td>6</td><td>8,5</td><td>15</td><td rowspan="3">800</td><td rowspan="4">120</td><td rowspan="4">Voir la Figure 2 et la Figure 3</td></tr>
<tr><td>As
mouillé [c]</td><td>12</td><td>17</td><td>30</td></tr>
<tr><td>As
sec [a, d]</td><td>25 (30)</td><td>35,4 (42,4)</td><td>60</td></tr>
<tr><td>B</td><td>50</td><td>71</td><td>120</td><td rowspan="3">Selon le Tableau 6 et le Tableau 7</td></tr>
<tr><td>C</td><td>1 000</td><td>4 500 [b]</td><td>1 500</td><td colspan="2" rowspan="2">Aucune limite</td></tr>
<tr><td>D</td><td>Aucune limite</td><td>Aucune limite</td><td>Aucune limite</td></tr>
</table>

[a] Pour les *BDM/CDM/PDS* comportant un seul circuit *CTD As*, les valeurs entre parenthèses s'appliquent.

[b] La valeur 4 500 V permet à tous les *PDS basse tension* d'être traités par le Tableau 6 (réflexions possibles jusqu'à $3 \times \sqrt{2} \times 1\,000\,\text{V} = 4\,242\,\text{V}$).

[c] La caractéristique assignée "extérieur sans condition" reflète les conditions de service environnementales selon le Tableau 20. Cette caractéristique assignée est admise uniquement si un contact est possible avec le bout du doigt. Pour information: Les valeurs sont déduites de l'IEC 60364-4-41:2016, 414.4.5.

[d] La caractéristique assignée "intérieur sans condition" reflète les conditions de service environnementales selon le Tableau 20. Pour information: Cette caractéristique assignée satisfait aux exigences d'emplacements secs selon l'IEC 61140.

[e] Les valeurs sont déduites de l'IEC 61140:2016, 5.2.6.

L'Article A.5 donne trois exemples de différentes formes d'onde de *tension de fonctionnement* et fournit les méthodes d'évaluation de la tension à l'étude correspondant aux niveaux de *CTD* du Tableau 2.

Les limites de tension de contact non répétitive à court terme pour les circuits *CTD As* et *CTD B* pendant et après des *conditions anormales de fonctionnement* et une *condition de premier défaut* et sont données à la Figure 2, la Figure 3 et la Figure 4. Les valeurs du tableau pour *CTD B* sont des valeurs en régime permanent issues des figures.

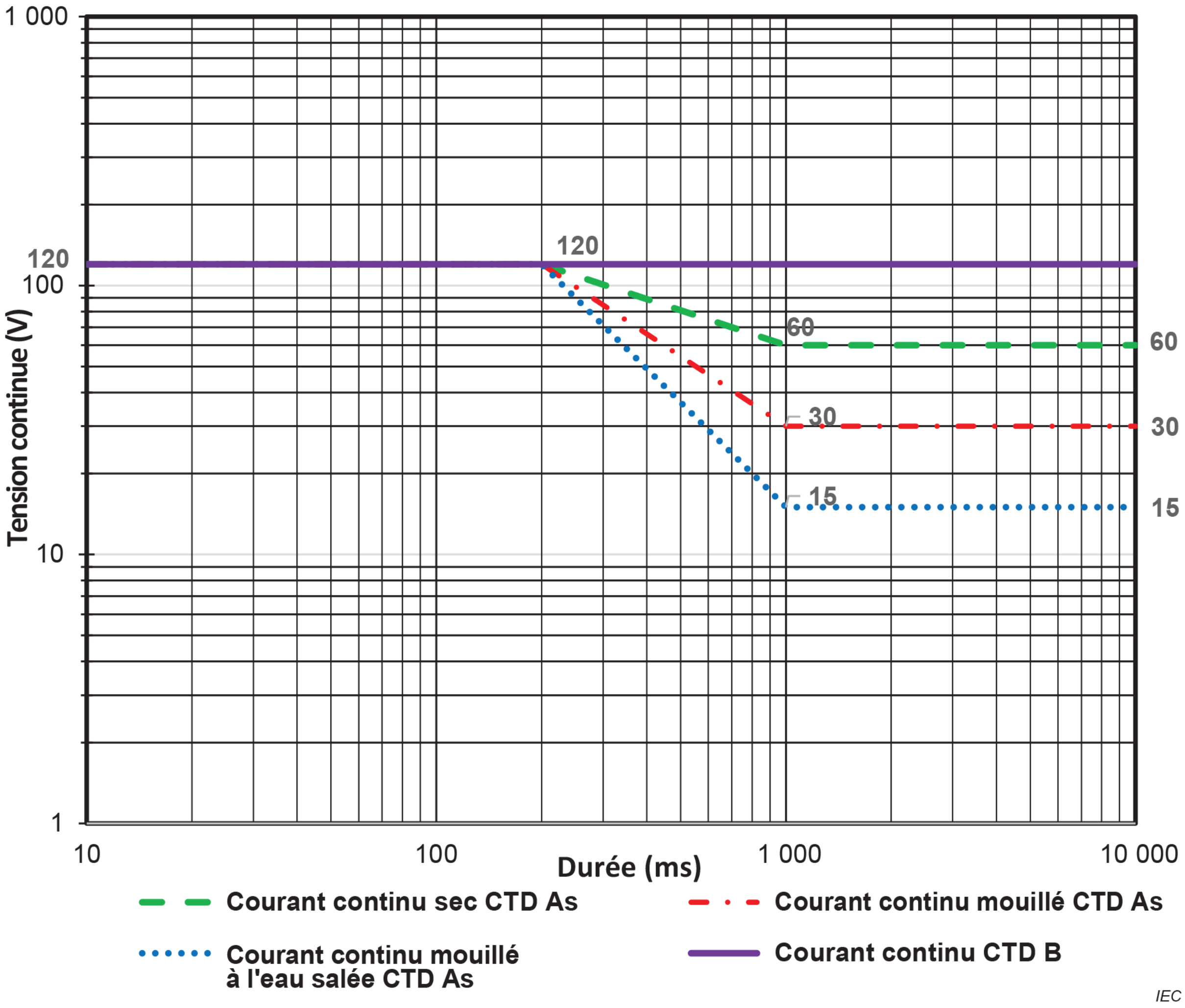


Figure 2 – Zones temps-tension pour les circuits *CTD As* et *CTD B* – Courant continu

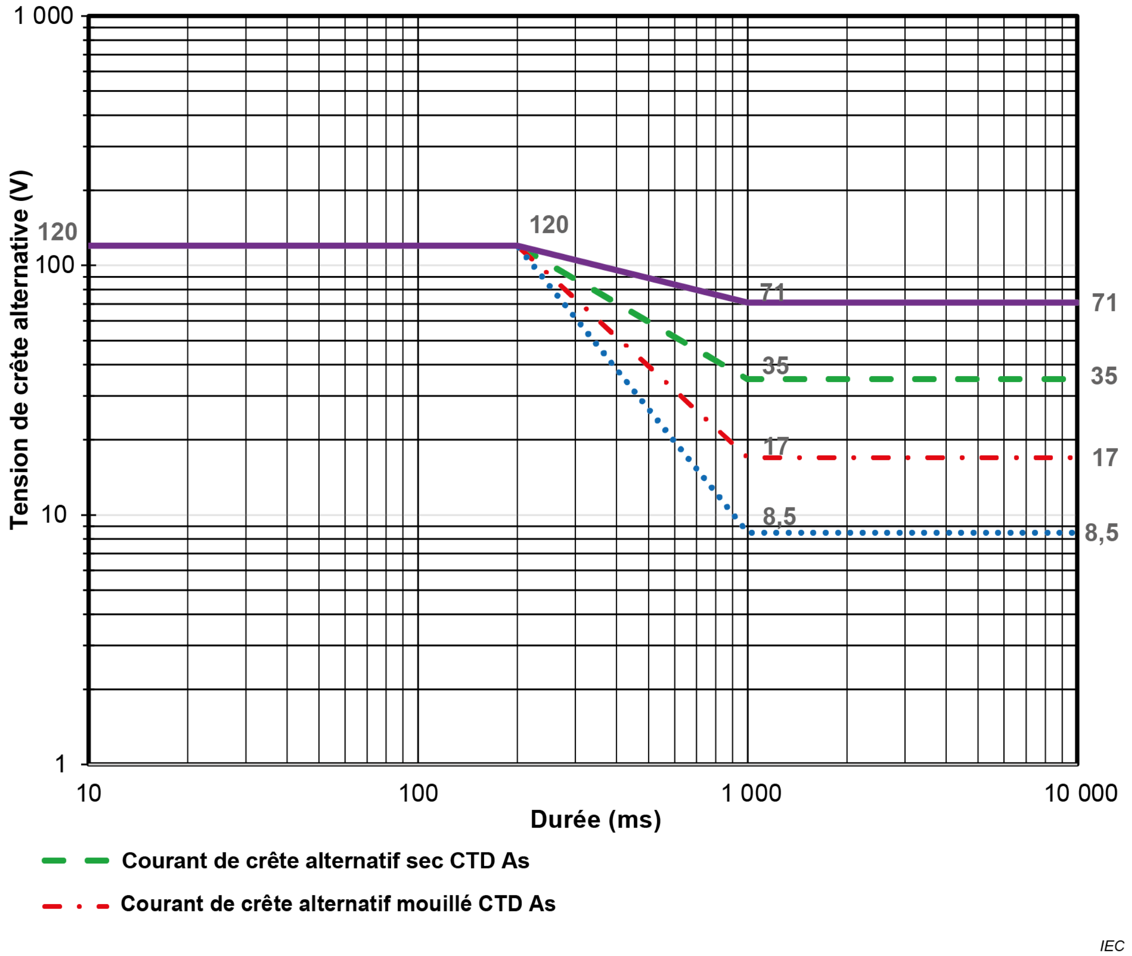


Figure 3 – Zones temps-tension pour les circuits *CTD As* et *CTD B* – Crête en courant alternatif

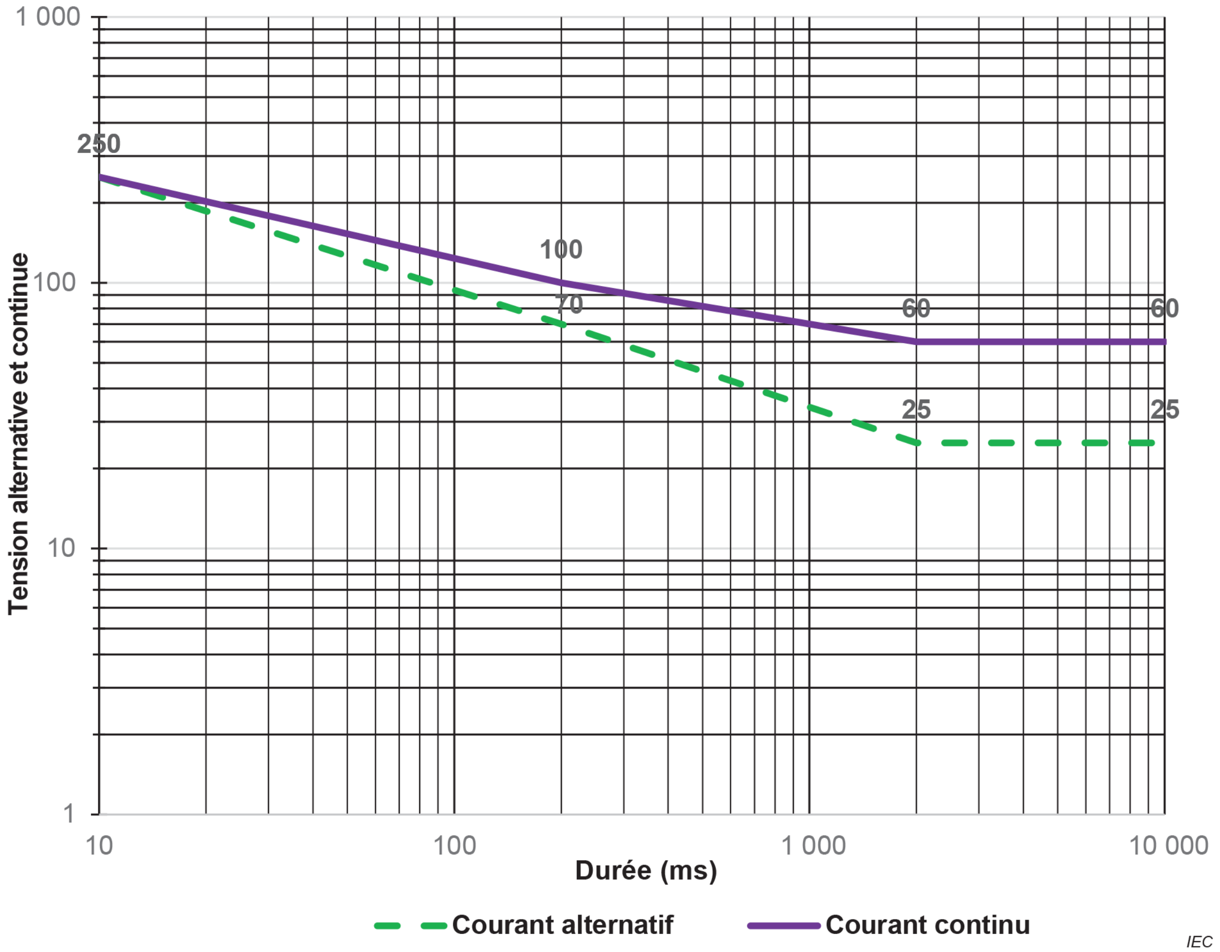


Figure 4 – Zones temps-tension pour les *parties accessibles* conductrices

Dans les limites de 1 000 ms pour les circuits accessibles et de 2 000 ms pour les parties *accessibles* conductrices, la tension doit diminuer à la valeur en régime permanent indiquée dans le Tableau 2 ou le défaut doit être interrompu par un dispositif de protection.

Dans les *conditions de premier défaut*, si un dispositif de protection est utilisé, ses caractéristiques doivent assurer que les limites temps-tension indiquées à la Figure 4 ne sont pas dépassées. Si un dispositif de protection externe est utilisé, le fabricant du *BDM/CDM/PDS* doit donner des informations relatives à ses caractéristiques dans le manuel d'installation.

Pour les essais, voir 5.2.4.

Pour le marquage, voir 6.3.9.6.

4.4.2.7 Exigences de protection contre les chocs électriques

Le Tableau 3 présente les solutions possibles pour assurer la conformité à 4.4 en cas d'application d'une *protection principale* ou d'une *protection renforcée*, en fonction de la *CTD* du circuit à l'étude en 4.4.2 et des *circuits adjacents*.

Les exigences du présent document en matière de protection contre les chocs électriques peuvent être satisfaites par d'autres moyens que ceux présentés dans le Tableau 3, auquel cas l'analyse de défaillance et les essais doivent démontrer que les exigences du 4.1 et du 4.4 sont satisfaites.

Tableau 3 – Exigences de protection pour les circuits à l'étude

***CTD* du circuit à l'étude**	**Protection des *parties accessibles* conductrices connectées à la terre de protection**	**Protection des *parties accessibles* conductrices non connectées à la terre de protection**[c]	**Protection du *circuit adjacent***				
			***As* Mouillé**	***As* Sec**	***B***	***C***	***D***
As Mouillé	Aucune 1 ou 3	Aucune 1	1[a] ou 2[b]	*Protection principale*	*Protection principale*	*Protection renforcée*	*Protection renforcée*
As Sec	Aucune 1 ou 3	Aucune 1	--	1[a] ou 2[b]	*Protection principale*	*Protection renforcée*	*Protection renforcée*
B	*Protection principale* [d]	*Protection principale* [d]	--	--	1[a] ou 2[b]	*Protection renforcée* [e]	*Protection renforcée*
C	*Protection principale*	*Protection renforcée*	--	--	--	2	*Protection renforcée*
D	*Protection principale*	*Protection renforcée*	--	--	--	--	2

Protection principale, voir 4.4.3.2.

Protection renforcée, voir 4.4.5.

La ligne "*As* Mouillé" couvre la *CTD As* mouillée et la *CTD As* mouillée à l'eau salée.

1 La protection n'est pas nécessaire pour la sécurité, mais peut être exigée pour des raisons fonctionnelles, conformément à 4.4.7.3.

2 *Protection principale* du circuit de tension supérieure.

3 Si le circuit concerné est un *circuit TBTS*, la *protection principale* est exigée avec la terre et les *circuits TBTP*.

1 ou 2 En fonction de la séparation avec les autres circuits.

NOTE Les exigences de protection de ce tableau considèrent que la *CTD C* et la *CTD D* peuvent être reliées au *réseau*.

[a] Les deux circuits à l'étude présentent le même niveau de tension.

[b] Les deux circuits à l'étude présentent un niveau de tension différent.

[c] S'applique également aux parties conductrices connectées à la terre fonctionnelle.

[d] Il n'y a aucune exigence de protection pour *CTD B* aux *parties accessibles* dans les *zones d'accès pour la maintenance* ou les *zones d'accès limité*, et fait référence à 4.4.3.3 et 4.11.1 pour les exigences relatives à l'accessibilité et à l'*isolation* du câble.

[e] Pour les circuits dans les limites de tension de *CTD B* qui ne satisfont pas à 4.4.2.3.b), il est admis d'utiliser la *protection principale* pour le circuit de tension supérieure si la protection contre le contact direct est appliquée au circuit *CTD B*.

Des exemples sont donnés à l'Annex A afin d'assurer la protection contre les chocs électriques.

Pour assurer l'intégrité du *système d'isolation* du *BDM/CDM/PDS*, le fabricant d'un *BDM/CDM/PDS* doit indiquer la tension maximale dont la connexion à chaque *accès* est admise.

Pour le marquage, voir 6.2 et 6.3.9.1.

4.4.3 Dispositions en matière de *protection principale*

4.4.3.1 Généralités

La *protection principale* est utilisée pour empêcher les personnes de toucher les *parties actives dangereuses*. Elle doit être fournie par au moins l'une des mesures données en a) ou b):

a) protection au moyen de l'*isolation principale* des *parties actives dangereuses* en 4.4.3.2; ou

b) protection au moyen d'enveloppes ou de barrières en 4.4.3.3.

NOTE Pour les *installations*, *systèmes* et équipements *basse tension*, la *protection principale* de l'IEC 60364-4-41 correspond en général à la "protection contre les contacts directs" précédemment utilisée, le plus souvent en ce qui concerne la défaillance de l'*isolation principale*.

4.4.3.2 Protection au moyen de l'*isolation principale* des *parties actives dangereuse*

L'isolation principale peut être assurée par l'isolation solide ou la distance d'isolement.

L'*isolation principale* doit être conçue selon 4.4.7.2.1 pour les circuits auxquels elle est connectée, en tenant compte de

- la *tension de tenue aux chocs*,
- la *surtension temporaire,* et
- la *tension de fonctionnement*

selon celle qui donne les exigences les plus strictes.

Il ne doit pas être possible de retirer l'*isolant* sans utiliser d'outil ou de clé.

Une *partie accessible* conductrice est considérée comme étant conductrice si sa surface est nue ou recouverte d'une couche d'isolant qui ne satisfait pas aux exigences de l'*isolation* appropriées selon le Tableau 3.

Toute *partie accessible* conductrice est considérée comme une *partie active dangereuse* si elle n'est pas séparée des *parties actives* de façon à satisfaire au moins aux exigences minimales de protection du Tableau 3.

Pour les essais, voir 5.2.3.2 et 5.2.3.4.

L'Article A.6 donne des exemples d'utilisation d'éléments de mesures de protection.

4.4.3.3 Protection au moyen d'*enveloppes* ou de barrières

4.4.3.3.1 Généralités

Les *parties actives dangereuses* doivent être placées dans des *enveloppes* ou derrière des barrières satisfaisant au moins aux exigences IP2X conformément à l'IEC 60529.

NOTE Le fait d'exiger IP2X au lieu d'IPXXB a pour objet de limiter les ouvertures à moins de 12,5 mm en petite dimension, sinon les ouvertures jusqu'à 50 mm de diamètre (ou 20 mm en petite dimension quelle que soit la longueur) peuvent être admises. La longueur de 12,5 mm est exigée pour assurer la protection contre les objets solides étrangers.

Il doit uniquement être possible d'ouvrir les *enveloppes* ou de retirer les barrières:

- à l'aide d'un outil ou d'une clé, ou
- après avoir mis ces *parties actives dangereuses* hors tension.

Des exemples d'ouvertures dans les *enveloppes* sont donnés en A.6.3 et dans le Tableau A.1.

Pour les essais, voir 5.2.2.2 et 5.2.2.3.

4.4.3.3.2 *Zones d'accès pour la maintenance*

Les produits contenant des circuits de *CTD B, CTD C* ou *CTD D,* dans lesquels la protection contre les chocs électriques est assurée par la *zone d'accès pour la maintenance*, n'ont pas besoin de mesures de *protection principale.* Il doit être exigé d'utiliser un outil ou une clé pour accéder à la zone, et la conformité à a) ou b) est exigée.

a) Les exigences de marquage du 6.3.9.1.1 doivent s'appliquer; et
   - *parties actives dangereuses accessibles* doivent être protégées au moins au niveau IPXXA; et
   - *parties actives dangereuses* qui risquent d'être touchées lors de réglages doivent être protégées au moins au niveau IPXXB.

b) Les exigences de marquage du 6.3.9.1.1 et du 6.3.9.1.2 doivent s'appliquer.

4.4.3.3.3 *Zones d'accès limité*

Les produits contenant des circuits de la *CTD B* ou de la *CTD C* et qui sont destinés à être installés dans des *zones d'accès limité* uniquement n'ont pas besoin de mesures de *protection principale*. Toutefois, ils exigent l'utilisation d'un outil ou d'une clé pour accéder à la zone et doivent être marqués conformément aux exigences du 6.3.9.1.

Les produits contenant des circuits de la *CTD D* et destinés à être installés dans une *zone d'accès limité* font l'objet des exigences supplémentaires du 4.4.10.

4.4.3.3.4 *BDM/CDM* de *type ouvert* et sous-ensembles

Les *BDM/CDM* de *type ouvert* et sous-ensembles n'exigent pas de mesures de *protection principale*. Ces informations fournies avec le *BDM/CDM* doivent indiquer que la protection doit être assurée dans l'*installation*.

Pour le marquage, voir 6.2.1 et 6.3.6.

4.4.3.3.5 Surfaces supérieures des *enveloppes* ou des barrières

4.4.3.3.5.1 Généralités

Les surfaces supérieures des *enveloppes* ou des barrières, qui sont accessibles lorsque le *BDM/CDM/PDS* est sous tension et sous lesquelles se trouvent les *parties actives dangereuses*, doivent satisfaire aux exigences du niveau IPXXC.

NOTE Les surfaces supérieures sont la projection des surfaces par rapport à la verticale.

Pour le marquage, voir 6.3.2.

Pour les *BDM/CDM/PDS* dont les surfaces supérieures ne sont pas définies ou qui sont *déplaçables*, les exigences du niveau IPXXC s'appliquent à toutes les surfaces supérieures raisonnablement possibles.

Voir 5.2.2.2 pour l'essai.

4.4.3.3.5.2 Protection contre la chute verticale d'objets

Les ouvertures dans les *enveloppes* ou barrières doivent être placées ou construites de sorte qu'il soit improbable que des objets tombant à la verticale entrent dans l'*enveloppe* et provoquent un danger électrique.

Une ouverture doit être inférieure à 2,5 mm en petite dimension, sauf si une analyse réalisée selon 4.2 peut démontrer que la construction fournit une protection adaptée.

Une ouverture de ventilation sur la surface supérieure d'un *BDM/CDM* qui n'est pas de *type ouvert* doit être recouverte par une hotte ou un blindage de protection espacé au-dessus de l'ouverture en présence de *parties actives non isolées* en dessous l'orifice

NOTE Aux États-Unis et au Canada, cela s'applique aux *enveloppes* de Type 1.

Pour les *BDM/CDM/PDS déplaçables* dont le haut et le bas ne sont pas définis, cette exigence s'applique à tous les côtés.

La conformité est vérifiée par l'*inspection visuelle* du 5.2.1.

Pour le marquage, voir 6.3.2.

4.4.4 Dispositions en matière de *protection en cas de défaut*

4.4.4.1 Généralités

La *protection en cas de défaut* est exigée pour empêcher les chocs électriques qui peuvent découler du contact avec les *parties accessibles* conductrices pendant et après la défaillance de la *protection principale* du 4.4.3.

La *protection en cas de défaut* doit être assurée par au moins l'une des mesures suivantes a), b), c), d) ou e):

a) *liaison équipotentielle de protection* du 4.4.4.2 en combinaison avec le *conducteur de mise à la terre de protection* externe du 4.4.4.3;
b) déconnexion automatique de l'alimentation du 4.4.4.4;
c) *isolation supplémentaire* du 4.4.4.5;
d) *protection principale* entre les circuits du 4.4.4.6;
e) *écran de protection électrique* du 4.4.4.7.

La *protection en cas de défaut* doit être indépendante de la *protection principale* 4.4.3 et la compléter.

NOTE Pour les *installations*, *systèmes* et équipements *basse tension*, la *protection en cas de défaut* correspond en général à la protection contre les contacts indirects utilisée dans l'IEC 60364-4-41, le plus souvent en ce qui concerne la défaillance de l'*isolation principale*.

4.4.4.2 *Liaison équipotentielle de protection*

4.4.4.2.1 Généralités

La *liaison équipotentielle de protection* est une disposition en matière de *protection en cas de défaut* permettant d'activer la protection contre les chocs électriques.

Le circuit de *liaison équipotentielle de protection* est composé de l'interconnexion:

- des moyens de connexion du *conducteur de mise à la terre de protection (borne(s) PE)* du *BDM/CDM/PDS* (voir 4.4.4.3.2);
- des *conducteurs de mise à la terre de protection* (4.4.4.3) dans et entre les parties du *BDM/CDM/PDS*, y compris les contacts glissants dans lesquels ils font partie intégrante du circuit (voir la Figure 5 et la Figure 6);
- des *parties accessibles* conductrices du *BDM/CDM/PDS (*voir la Figure 5 et la Figure 6), et
- des parties structurelles conductrices du *BDM/CDM/PDS (*voir la Figure 5 et la Figure 6).

La *liaison équipotentielle de protection* doit être placée entre les *parties accessibles* conductrices du *BDM/CDM/PDS* et les moyens de connexion du *conducteur de mise à la terre de protection* afin de faciliter la déconnexion automatique de l'alimentation selon 4.4.4.4, sauf

a) les *parties accessibles* conductrices protégées par l'une des mesures du 4.4.6.4, ou
b) lorsque les *parties accessibles* conductrices sont séparées des *parties actives dangereuses* par une *protection renforcée* (*double isolation* ou *isolation renforcée*, par exemple).

La *liaison équipotentielle de protection* doit être convenablement protégée contre les dommages mécaniques, les dégradations chimiques ou électrochimiques, les forces électrodynamiques et thermodynamiques.

Les points de connexion électrique de la *liaison équipotentielle de protection* doivent être résistants à la corrosion.

Les connexions électriques des circuits de *liaison équipotentielle de protection* doivent être conçues de manière à ne pas transmettre la pression de contact par le matériau isolant, sauf si la résilience des parties métalliques est suffisante pour compenser l'éventuel rétrécissement ou déformation du matériau isolant.

Chaque connexion (vissée, colliers) entre la *liaison équipotentielle de protection* et d'autres équipements doit assurer une continuité électrique durable et une résistance mécanique et une protection adaptées.

Les vis de connexion de la *liaison équipotentielle de protection* ne doivent pas servir à d'autres fins, à moins que le fabricant ne le spécifie dans le manuel d'installation et de maintenance.

Pour le marquage, voir 6.3.9.3.

Si la borne de la *liaison équipotentielle de protection* est identifiée par une combinaison des couleurs rouge et jaune ou par le symbole IEC 60417-5019:2006-08, elle doit également satisfaire aux exigences du 4.4.4.3.2.

Le contact électrique sur les dispositifs de connexion du *conducteur de mise à la terre de protection* doit être effectué par au moins l'une des méthodes suivantes a), b), c) ou d):

a) par l'intermédiaire d'un contact métallique direct (pour un exemple, voir la Figure 6, légende 8);
b) par l'intermédiaire d'autres *parties accessibles* conductrices ou d'autres *composants* métalliques qui ne sont pas retirés lorsque le *BDM/CDM/PDS* est utilisé comme prévu;
c) par l'intermédiaire d'un conducteur de *liaison équipotentielle de protection* dédié (voir la Figure 5);
d) par l'intermédiaire d'*enveloppes*, de parois ou de châssis métalliques.

Lorsque des surfaces peintes (en particulier des surfaces peintes avec de la poudre) sont jointes, un masquage de la peinture, des méthodes de poinçonnage de la peinture ou une connexion séparée doivent être utilisés pour assurer un contact fiable.

Lorsque l'équipement électrique est monté sur des couvercles, des *portes* ou des *capots*, la continuité du circuit de *liaison équipotentielle de protection* doit être assurée par un conducteur prévu à cet effet ou des moyens équivalents satisfaisant aux exigences en matière de *liaison équipotentielle de protection*. Si les fixations, charnières ou contacts glissants ne fournissent pas et ne garantissent pas une impédance suffisamment faible, une liaison parallèle suffisante est exigée.

Sauf spécification du fabricant et conformément à 4.4.4.2.2, les conduits métalliques flexibles ou rigides et les gaines de câble métalliques ne doivent pas servir de moyens de *liaison équipotentielle de protection*. Voir 6.3.9.3.

Toutefois, ces conduits, gaines et conducteurs non utilisés métalliques doivent être connectés au circuit de *liaison équipotentielle de protection* sur une extrémité au moins afin d'éviter la tension dangereuse due au couplage capacitif ou inductif des conducteurs adjacents.

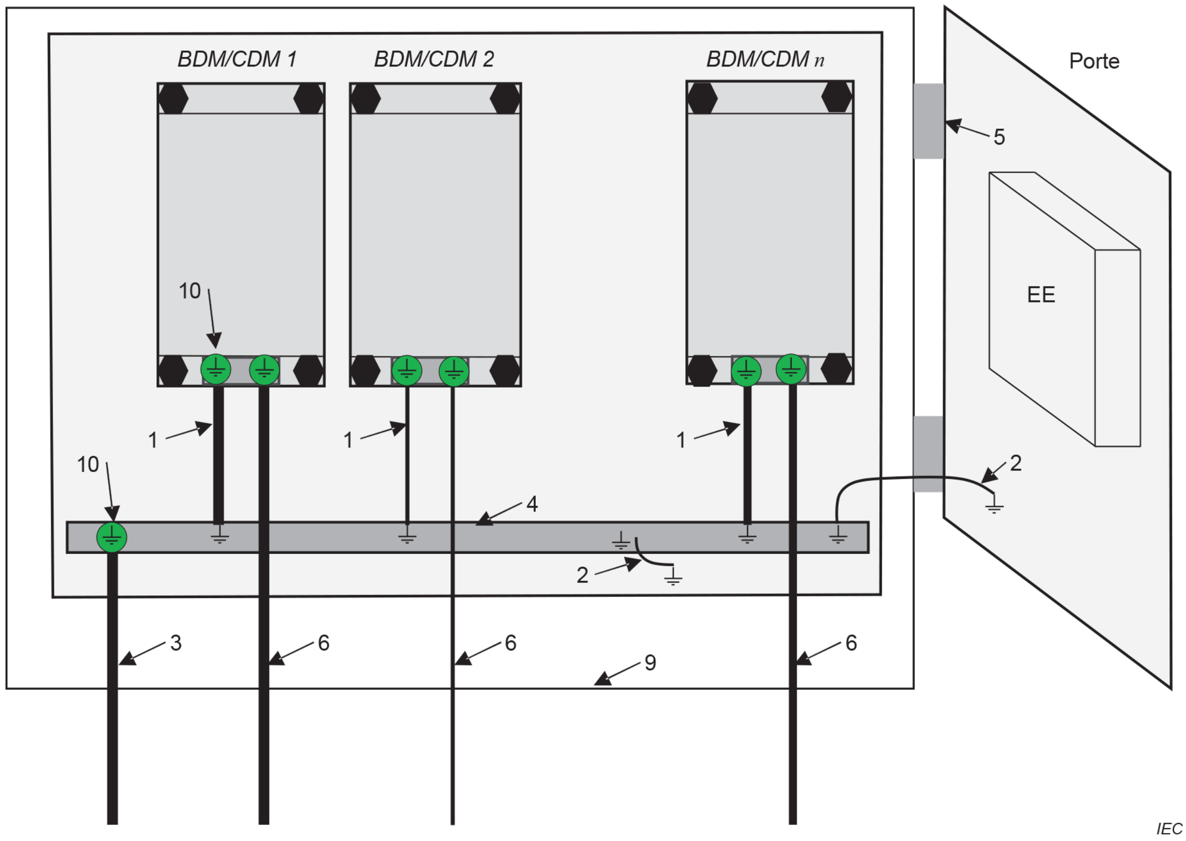
NOTE 1 Pour des raisons liées à la CEM selon l'IEC 61800-3, une connexion aux deux extrémités peut être exigée.

Pour les circuits *CTD C* et *CTD D* d'un *BDM/CDM/PDS*, si une seule extrémité de ce conduit ou de cette gaine est raccordée au circuit de *liaison équipotentielle de protection*, l'autre extrémité doit

- comporter une *protection principale* selon 4.4.3.3, ou
- être raccordée à la terre par le circuit de *liaison équipotentielle de protection* avec une impédance permettant de limiter toute tension induite à une valeur maximale de *CTD As*.

Le circuit de *liaison équipotentielle de protection* ne doit pas intégrer de *composant* tel qu'un commutateur ou des dispositifs de protection contre les *surintensités* destinés à ouvrir le circuit.

Un exemple de disposition *BDM/CDM* relevant de la *protection de classe I* et sa *liaison équipotentielle de protection* associée est présenté à la Figure 5.



Légende

1 *liaison équipotentielle de protection* des sous-systèmes ou *conducteur de mise à la terre de protection* du *BDM/CDM* (dimensionné selon les exigences relatives au *PDS*) (voir 4.4.4.2 ou 4.4.4.3)

2 *liaison équipotentielle de protection* (voir 4.4.4.2)

3 *conducteur de mise à la terre de protection* (dimensionné selon les exigences relatives au *PDS*) vers un point de mise à la terre de l'*installation* (voir 4.4.4.3)

4 barre de *terre*

5 charnière

6 *conducteur de mise à la terre de protection* vers le moteur ou une autre charge (voir 4.4.4.3)

7 non utilisé

8 non utilisé

9 *enveloppe* de la disposition BDM/CDM relevant de la *protection de classe I*

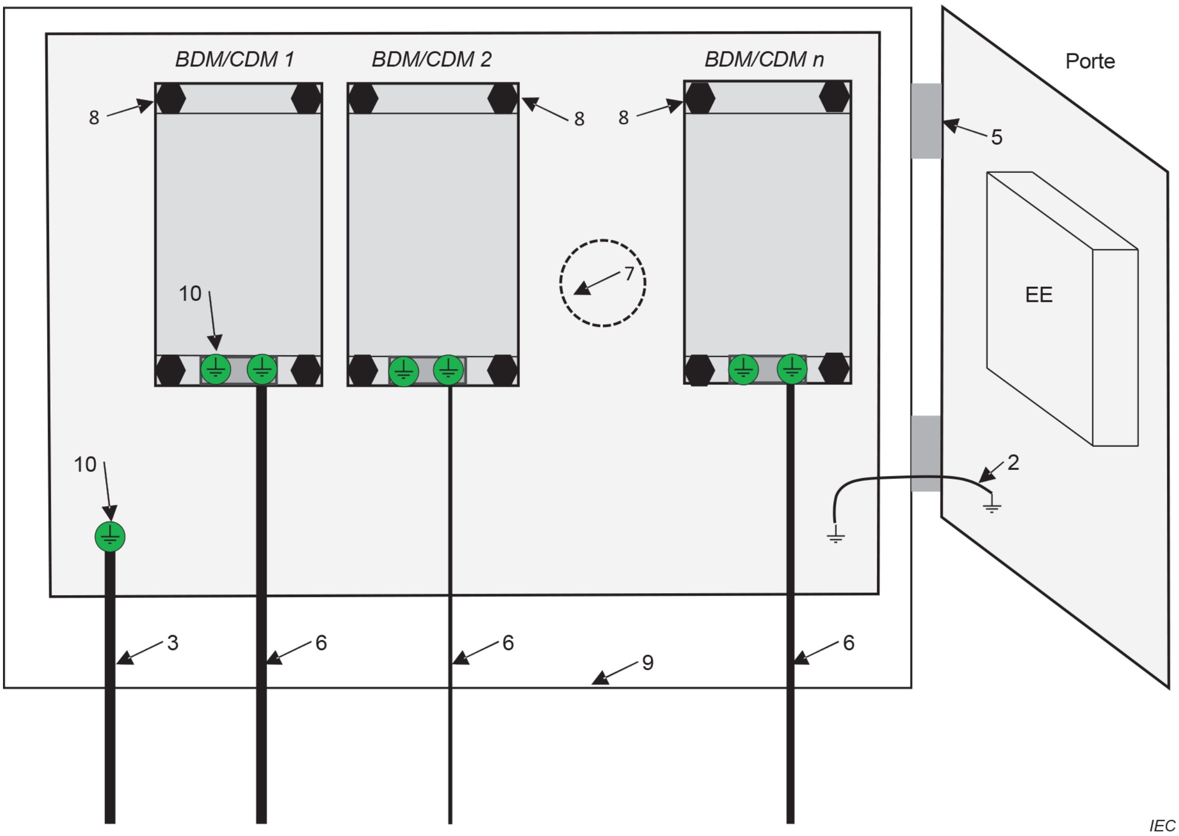
10 moyens de raccordement du conducteur de mise à la terre de protection (voir 4.4.4.3 et 4.4.4.3.2)

EE autre équipement électrique (relié à la masse si cela est approprié pour cet équipement))

NOTE Les moteurs ne sont pas présentés.

Figure 5 – Exemple de disposition *BDM/CDM* relevant de la *protection de classe I* et sa *liaison équipotentielle de protection* associée

Un exemple de disposition *BDM/CDM* relevant de la *protection de classe I* et sa *liaison équipotentielle de protection* associée par l'intermédiaire d'un contact métallique direct est présenté à la Figure 6.



Légende

1 non utilisé

2 *liaison équipotentielle de protection* (voir 4.4.4.2)

3 *conducteur de mise à la terre de protection* (dimensionné selon les exigences relatives au *PDS*) vers un point de mise à la terre de l'*installation* (voir 4.4.4.3)

4 non utilisé

5 charnière

6 *conducteur de mise à la terre de protection* vers le moteur ou une autre charge (voir 4.4.4.3)

7 sous-plaque métallique utilisée comme *liaison équipotentielle de protection*

8 *liaison équipotentielle de protection* par l'intermédiaire d'un contact métallique direct conformément aux manuels d'installation et de maintenance du fabricant

9 *enveloppe* de la disposition BDM/CDM relevant de la *protection de classe I*

10 moyens de raccordement du *conducteur de mise à la terre de protection* (voir 4.4.4.3 et 4.4.4.3.2)

EE autre équipement électrique (relié à la masse si cela est approprié pour cet équipement)

NOTE 1 Les moteurs ne sont pas présentés.

NOTE 2 La légende 8 et la Légende 10 du *BDM/CDM* ont le même potentiel que le *conducteur de mise à la terre de protection*.

Figure 6 – Exemple de disposition *BDM/CDM* relevant de la *protection de classe I* et sa *liaison équipotentielle de protection* associée par l'intermédiaire d'un contact métallique direct

NOTE 2 Pour plus d'informations, voir l'IEC 60364-5-54:2011, 543.2.2.

4.4.4.2.2 Caractéristiques de la liaison équipotentielle de protection

Toutes les parties d'une *liaison équipotentielle de protection* entre toutes les parties du *BDM/CDM/PDS* doivent

a) être dimensionnées conformément à toutes les exigences du 4.4.4.3 afin d'assurer qu'aucune chute de tension ne dépasse les limites de la *CTD As* du 4.4.2.2 et de la Figure 4 en cas de *condition de premier défaut*, ou

b) être dimensionnées

   - de manière à résister aux contraintes les plus élevées qui peuvent se produire sur l'élément ou les éléments concernés du *PDS* lorsqu'ils font l'objet d'un défaut les raccordant à des *parties accessibles* conductrices,
   - de manière à rester efficace tant que le défaut sur les *parties accessibles* conductrices persiste ou jusqu'à ce qu'un dispositif de protection en amont supprime le courant dans ces parties, et
   - de manière à assurer qu'aucune chute de tension ne dépasse les limites de la *CTD As* du 4.4.2.2 et de la Figure 4 en conditions normales de fonctionnement et en cas de *condition de premier défaut*.

S'il s'agit du seul moyen de *liaison équipotentielle de protection* à l'intérieur du circuit, l'essai de routine prévu au point 5.2.3.11.2 est requis.

La conformité à a) n'exige pas de procéder à des essais de type.

La conformité à b) doit être vérifiée par les essais de type du 5.2.3.11.1.

4.4.4.3 *Conducteur de mise à la terre de protection*

4.4.4.3.1 Généralités

Un *conducteur de mise à la terre de protection* doit toujours être connecté lorsque le *BDM/CDM/PDS* est alimenté, sauf si le *BDM/CDM/PDS* satisfait aux exigences de *protection de classe II* (voir 4.4.6.3) et de *protection de classe III* (voir 4.4.6.4).

Sauf indication contraire des règlements de câblages locaux, la section du *conducteur de mise à la terre de protection* doit être déterminée à partir du Tableau 4 ou par des calculs établis selon l'IEC 60364-5-54:2011, 543.1.

La conformité aux exigences du 4.4.4.3.3 doit être confirmée afin d'assurer un risque réduit en cas de défaillance du *conducteur de mise à la terre de protection*.

Si le *conducteur de mise à la terre de protection* est raccordé par une prise ou tout autre moyen similaire de déconnexion,

- la déconnexion doit être impossible tant que la partie à protéger n'est pas d'abord mise hors tension, ou
- le *conducteur de mise à la terre de protection* doit être le dernier conducteur à être interrompu dans les conditions normales et les *conditions de premier défaut*.

Tableau 4 – Section du *conducteur de mise à la terre de protection*

Section des conducteurs de phase du *PDS* S en mm^2	**Section minimale du *conducteur de mise à la terre de protection* correspondant** [a] S_{PE} en mm^2
$S \leq 16$	S
$16 < S \leq 35$	16
$35 < S$	$S/2$

[a] Ces valeurs ne sont valables que si le *conducteur de mise à la terre de protection* est constitué du même matériau que les conducteurs de phase. Dans le cas contraire, la section du *conducteur de mise à la terre de protection* doit être déterminée de façon telle que la conductivité soit égale à celle résultant de l'application des valeurs de ce tableau.

La section de chaque *conducteur de mise à la terre de protection* qui ne fait pas partie du câble d'alimentation multiconducteur ou du câble d'armoire ne doit en aucun cas être inférieure à

- 2,5 mm^2 en présence d'une protection mécanique (voir 4.11.2.2), ou
- 4 mm^2 sans protection mécanique.

4.4.4.3.2 Dispositifs de raccordement du *conducteur de mise à la terre de protection*

Le *BDM/CDM/PDS* doit comporter des dispositifs de raccordement du *conducteur de mise à la terre de protection,* situés à proximité des bornes pour les conducteurs actifs respectifs.

Les dispositifs de raccordement doivent être résistants à la corrosion et doivent être adaptés aux conducteurs du Tableau 4 ainsi qu'aux câbles conformes aux règles de raccordement applicables à l'*installation* (voir 4.4.4.3.3, 4.11.11.2 et 4.11.11.3).

NOTE Aux États-Unis, les dispositifs de raccordement doivent être adaptés à un conducteur comme cela est spécifié dans la Section 250.122 et le Tableau 250.122 du National Electrical Code ANSI/NFPA 70.

Les dispositifs de raccordement du *conducteur de mise à la terre de protection* ne doivent ni être utilisés en tant que partie de l'assemblage mécanique du *BDM/CDM/PDS* ni pour d'autres raccordements.

Les vis et écrous de serrage du *conducteur de mise à la terre de protection* ne doivent pas servir à fixer d'autres *composants*, bien qu'ils puissent maintenir les bornes en place ou empêcher leur rotation.

Le raccordement et les points de liaison de protection doivent être conçus pour que leur courant admissible ne soit pas altéré par des influences mécaniques, chimiques ou électrochimiques.

En présence d'*enveloppes* et/ou de conducteurs en aluminium ou alliage d'aluminium, il convient particulièrement de veiller aux problèmes de corrosion électrolytique.

La conformité doit être vérifiée par l'*inspection visuelle* du 5.2.1.

L'Annex K donne des informations supplémentaires relatives à la corrosion électrochimique.

Pour le marquage, voir 6.3.9.2.2.

Le marquage ne doit pas être apposé ou fixé au moyen de vis, de rondelles ou d'autres pièces susceptibles d'être enlevées au moment de la connexion des conducteurs.

Tous les dispositifs de raccordement du *conducteur de mise à la terre de protection*, y compris les vis et les bornes, marqués selon 6.3.9.2.2 doivent satisfaire aux exigences du 4.4.4.3.2.

4.4.4.3.3 *Courant de contact* en cas de défaillance du *conducteur de mise à la terre de protection*

Les exigences du 4.4.4.3.3 doivent être satisfaites afin d'éviter que les *parties accessibles* conductrices ne deviennent dangereuses en cas de dommage ou de déconnexion du *conducteur de mise à la terre de protection*.

Pour les *équipements enfichables de type A*, le *courant de contact* ne doit pas dépasser les limites indiquées en 4.4.5.4.

Pour tous les autres *BDM/CDM/PDS*, au moins l'une des mesures suivantes a) ou b) doit être appliquée, sauf s'il peut être démontré que le *courant de contact* est inférieur aux limites indiquées en 4.4.5.4:

a) utiliser un *BDM/CDM/PDS connecté en permanence* ainsi qu’un des moyens suivants:
   - un dispositif de raccordement pour un *conducteur de mise à la terre de protection* de section minimale de 10 mm^2 Cu ou 16 mm^2 Al (*conducteur de mise à la terre de protection* renforcé*)*;
   - la présence d'une borne supplémentaire pour un *conducteur de mise à la terre de protection* de section identique à celle du *conducteur de mise à la terre de protection* d’origine (second *conducteur de mise à la terre de protection)*; ou
   - le *conducteur de mise à la terre de protection* est totalement intégré dans les *enveloppes* de l'équipement électrique ou protégé sur toute sa longueur contre les dommages mécaniques (voir 4.11.2.2);

   ou

b) Utiliser un *équipement connecté en permanence* ou *enfichable de type B* avec une section minimale du *conducteur de mise à la terre de protection* de 2,5 mm^2 dans un câble d’alimentation multiconducteur. Un support d’attache conforme à 4.12.6 doit être fourni.

S'il est prévu et admis d'interconnecter au moins deux PDS à l'aide d'un *conducteur de mise à la terre de protection* commun, les exigences ci-dessus en matière de *courant de contact* s'appliquent au nombre maximal de PDS à interconnecter, sauf si l'une des mesures de a) ou b) ci-dessus est utilisée.

La conformité est vérifiée par l'*inspection visuelle* du 5.2.1 et par l'essai du 5.2.3.7.

Pour le marquage, voir 6.3.9.4.

4.4.4.3.4 Courant du *conducteur de mise à la terre de protection*

Dans les conditions normales de fonctionnement, le courant du *conducteur de mise à la terre de protection* en valeur efficace ne doit pas dépasser 5 % du courant d'entrée assigné du *BDM/CDM/PDS.*

NOTE Cette limitation du courant du *conducteur de mise à la terre de protection* provient de l'IEC 61140.

Si cette limite ne peut pas être satisfaite pour des raisons fonctionnelles ou autres en ce qui concerne les *BDM/CDM/PDS connectés en permanence* uniquement, en plus des mesures données en 4.4.4.3.3, le fabricant doit donner des informations dans le manuel de fonctionnement relatives aux mesures de protection suivantes, par exemple:

- le *conducteur de mise à la terre de protection* surdimensionné; ou
- *assurer* une *zone de liaison équipotentielle* dans les limites de 2,5 m à côté du *BDM/CDM/PDS*, par exemple ce qui suit:
  - les conduits métalliques;
  - les clôtures;
  - les échelles fixes;
  - les mains courantes;
  - connexion à la terre locale.

NOTE Voir l'IEC 60204-1:2016, Figure 4.

Pour le marquage, voir 6.3.9.4.

4.4.4.4 Déconnexion automatique de l'alimentation

4.4.4.4.1 Généralités

Pour la déconnexion automatique de l'alimentation en cas de défaillance de l'*isolation principale*,

- un *système de liaison équipotentielle de protection* doit être prévu, et
- un dispositif de protection (un fusible, un disjoncteur, un DDR, par exemple) actionné par le courant de défaut doit déconnecter au moins l'un des conducteurs de phase qui alimentent le *BDM/CDM/PDS*, comme partie intégrante du *système* ou de l'*installation*.

La déconnexion automatique de l'alimentation dépend de la *liaison équipotentielle de protection* opérable (voir 4.4.4.2) pendant la *durée de vie prévue*.

4.4.4.4.2 Interruption du courant de défaut dans les limites du temps imparti

Le dispositif de protection doit interrompre le courant de défaut dans le temps spécifié en 4.4.2.6.2 et l'IEC 60364-4-41:2005 et l'IEC 60364-4-41:2005/AMD1:2017, 411.3.2.2, 411.3.2.3 et 411.3.2.4, qui sont reproduits dans l'Article Q.1.

Si le dispositif de protection ne fait pas partie intégrante du *BDM/CDM/PDS,* des informations concernant sa sélection doivent être données dans le manuel d'installation.

Pour l'essai, voir 5.2.4.5.3 (voir également 4.3.1).

Pour le marquage, voir 6.3.9.6.3.

Si un dispositif de protection n'est pas en mesure d'interrompre l'alimentation conformément à l'IEC 60364-4-41:2005 et l'IEC 60364-4-41:2005/AMD1:2017, 411.3.2 ou si l'utilisation d'un DDR à cet effet n'est pas appropriée, voir 4.4.4.4.3.

Toutefois, la déconnexion peut être demandée pour d'autres raisons que la protection contre les chocs électriques.

4.4.4.4.3 Déconnexion automatique de l'alimentation impossible

Si la déconnexion automatique est impossible dans des conditions où

a) le *BDM/CDM* avec un courant de court-circuit limité au niveau de l'*accès* de puissance de sortie est installé, ou
b) les temps de déconnexion exigés en 4.4.4.4.2 ne peuvent pas être respectés par un dispositif de protection, ou
c) la protection contre les autres dangers est exigée (protection contre les dangers thermiques en 4.6, par exemple),

l'un des moyens suivants est applicable:

1) pour les *installation*s avec *BDM/CDM*, la tension au niveau de l'*accès* de puissance de sortie doit être réduite à 50 V en courant alternatif ou 120 V en courant continu, voire moins, par un circuit de protection électronique, qui se *déclenche* dans le délai indiqué en 4.4.4.4.2 en cas de défaut entre un conducteur actif et le *conducteur de mise à la terre de protection* ou la terre, le circuit de protection électronique étant soumis à un *essai de type* selon 5.2.4.5.3 et à la vérification selon 5.2.4.7;

   NOTE 1 Un "*circuit électronique de protection contre les courts-circuits en sortie de puissance*" est un exemple de "circuit de protection électronique qui se *déclenche*".

2) une *liaison équipotentielle de protection* supplémentaire doit être prévue selon l'IEC 60364-4-41:2005 et l'IEC 60364-4-41:2005/AMD1:2017, 415.2, et la tension entre les *parties accessibles* conductrices simultanément ne doit pas dépasser 50 V en courant alternatif ou 120 V en courant continu.

   NOTE 2 Voir l'Article Q.2.

NOTE 3 Par exemple, un moteur n'est pas alimenté à partir d'un *réseau,* mais à partir de l'*accès* de puissance de sortie d'un *BDM/CDM* par l'intermédiaire d'un long câble de moteur. En cas de défaillance dans le moteur, le courant peut être trop faible pour faire fonctionner la déconnexion automatique dans le délai imparti, en raison d'une limitation du courant de sortie au niveau de l'*accès* de puissance de sortie du *BDM/CDM* par un circuit de limitation de courant ou en raison de l'impédance du câble de moteur.

NOTE 4 En règle générale, le courant permanent disponible maximal au niveau de l'*accès* de puissance de sortie par rapport à la terre peut être utilisé comme valeur de *Ia* (voir l'Article Q.2) pour le calcul de la résistance de la *liaison équipotentielle de protection* supplémentaire, afin de respecter les limites de tension.

Pour le marquage, voir 6.3.9.6.3.

4.4.4.5 *Isolation supplémentaire*

L'*isolation supplémentaire* est une *isolation* indépendante appliquée en plus de l'*isolation principale* pour la *protection en cas de défaut*, et doit être dimensionnée pour résister aux mêmes contraintes que celles spécifiées pour l'*isolation principale*.

4.4.4.6 *Protection principale* entre les circuits

La *protection principale* entre un circuit et d'autres circuits ou la terre doit être assurée par l'*isolation principale*, adaptée à la tension la plus élevée présente.

Si un *composant* est connecté entre les circuits séparés, il doit satisfaire à 4.4.7.1.8.

Si un *composant* est connecté entre un circuit et un circuit relié à la terre, son impédance doit limiter le courant qui le traverse aux valeurs indiquées en 4.4.5.4.

4.4.4.7 *Écran de protection électrique*

Un *écran de protection électrique* placé entre les *parties actives dangereuses* d'un *BDM/CDM/PDS* doit être composé d'un écran conducteur raccordé à la *liaison équipotentielle de protection* du *BDM/CDM/PDS,* l'écran devant être séparé des *parties actives dangereuses* par au moins la *protection principale* 4.4.3.

L'*écran de protection électrique* et le raccordement au *système de liaison équipotentielle de protection* du *BDM/CDM/PDS* et cette interconnexion doivent satisfaire aux exigences du 4.4.4.2.

4.4.5 Mesures de *protection renforcée*

4.4.5.1 Généralités

La *protection renforcée* doit être totalement et effectivement maintenue quelles que soient les conditions prévues d'utilisation du *BDM/CDM/PDS*. La *protection renforcée* doit assurer à la fois la *protection principale* et la *protection contre les défauts* et peut être obtenue par l'une des dispositions suivantes ou par une combinaison de celles-ci:

a) *double isolation* dans 4.4.5.2;
b) *isolation renforcée* dans 4.4.5.3;
c) *impédance de protection* dans 4.4.5.4;
d) écran de protection électrique dans 4.4.4.7, l'écran étant séparé des *parties actives* par au moins la *protection principale* dans 4.4.3.

4.4.5.2 *Double isolation*

La *double isolation* doit comporter au moins deux *isolations*, l'une d'elles au moins devant satisfaire aux exigences d'*isolation principale* du 4.4.3.2 et l'autre devant satisfaire aux exigences d'*isolation supplémentaire* du 4.4.4.5.

4.4.5.3 *Isolation renforcée*

L'*isolation renforcée* doit être conçue de manière à être en mesure de résister aux contraintes électriques, thermiques, mécaniques et environnementales avec le même niveau d'*isolation* que celui proposé par la *double isolation* (*isolation principale* et *isolation supplémentaire*, voir 4.4.3.2 et 4.4.4.5), telles que présentées par conformité aux exigences de conception et d'essai pour l'*isolation renforcée* ailleurs dans le présent document.

4.4.5.4 Protection au moyen d'*impédances de protection*

L'*impédance de protection* doit être prévue de sorte que, dans des conditions normales de fonctionnement, dans des *conditions anormales de fonctionnement* et dans des *conditions de premier défaut,* le courant disponible et l'énergie de décharge ne doit pas dépasser

- une valeur de 3,5 mA en courant alternatif ou de 10 mA en courant continu pour la limitation du *courant de contact*, et
- une valeur de 0,5 mJ pour la limitation de l'énergie emmagasinée pour les tensions dépassant les limites de la *CTS As* du Tableau 2.

Voir l'Article A.3 et l'Article A.4 pour des exemples de ces mesures.

NOTE 1 Le développement des exigences de l'IEC 60990, de l'IEC 60479-1 et de l'IEC 60479-2 en ce qui concerne le courant de défaut avec une fréquence supérieure à 1 kHz sera pris en considération dans le cadre d'une révision future.

L'*impédance de protection* doit être conçue pour résister à la *tension de choc* et à la *surtension temporaire* des circuits auxquels elles sont raccordées. Voir 5.2.3.2 et 5.2.3.4 pour les essais.

La satisfaction aux exigences de limitation de courant est vérifiée par l'essai du 5.2.3.6.

La satisfaction aux exigences en matière d'énergie de décharge doit être vérifiée par des calculs et/ou des mesurages visant à déterminer la tension et la capacité.

NOTE 2 Une *impédance de protection* conçue selon 4.4.5.4 n'est pas considérée comme étant une connexion galvanique.

4.4.6 Mesures de protection

4.4.6.1 Généralités

La partie d'un *BDM/CDM/PDS* qui satisfait aux exigences du 4.4.6.2 se définit en *protection de classe I*.

La partie d'un *BDM/CDM/PDS* qui satisfait aux exigences du 4.4.6.3 se définit en *protection de classe II*.

La partie d'un *BDM/CDM/PDS* qui satisfait aux exigences du 4.4.6.4 se définit en *protection de classe III*.

Les mesures de protection du circuit *CTD As* dans un équipement relevant de la *protection de classe I* ou de la *protection de classe II* sont définies en 4.4.6.5.

NOTE 1 La protection de classe 0 selon l'IEC 61140:2016, 7.2 s'applique uniquement aux équipements destinés à être connectés au moyen d'un cordon et d'une prise à des circuits fonctionnant à une tension maximale de 150 V à la terre. C'est la raison pour laquelle la protection de classe 0 a été supprimée du présent document.

NOTE 2 L'IEC 61140 recommande que les normes de produits ne prennent plus en charge les équipements de classe 0.

La conformité doit être vérifiée en satisfaisant aux exigences de *protection de classe I,* de *protection de classe II* ou de *protection de classe III*.

Les *BDM/CDM/PDS relevant de la protection de classe I, de la protection de classe II et de la protection de classe III* doivent être marqués selon 6.3.9.2.

4.4.6.2 Mesures de protection des *BDM/CDM/PDS* relevant de la *protection de classe I*

Les *BDM/CDM/PDS* relevant de la *protection de classe I* doivent satisfaire aux exigences en matière de

- *protection principale* du 4.4.3, et
- *protection en cas de défaut* du 4.4.4 en ce qui concerne la *liaison équipotentielle de protection* du 4.4.4.2 et le *conducteur de mise à la terre de protection* du 4.4.4.3.

Voir la Figure A.7, exemple 1.

NOTE Dans un équipement relevant de *la protection de classe I* classique, la protection contre les chocs électriques est une combinaison des mesures de protection correspondant aux concepts de *protection de classe I,* de *protection de classe II* et de *CTD As*.

4.4.6.3 Mesures de protection des *BDM/CDM/PDS* relevant de la *protection de classe II*

Les *BDM/CDM/PDS* relevant de la *protection de classe II* doivent satisfaire aux exigences de *protection renforcée* selon 4.4.5. De plus, l'*enveloppe* doit satisfaire aux exigences de *protection principale* du 4.4.3.3 en ce qui concerne l'accessibilité aux *parties actives dangereuses*.

NOTE Aux États-Unis et au Canada, la protection par des méthodes de *protection de classe II* n'est pas applicable. (National Electrical Code ANSI/NFPA 70, Section 250.112).

Voir la Figure A.7 exemple 2 ou exemple 3.

Les *BDM/CDM/PDS* relevant de la *protection de classe II* ne doivent pas être un moyen de raccordement du *conducteur de mise à la terre de protection*. Toutefois, ceci ne s'applique pas dans le cas où un *conducteur de mise à la terre de protection* passe au travers du *BDM/CDM* vers un équipement raccordé en série en aval.

Dans le cas d'un *conducteur de mise à la terre de protection* qui passe au travers du *BDM/CDM/PDS*, le conducteur et son dispositif de raccordement doivent être séparés

- des *parties accessibles* ou surfaces accessibles conductrices du *BDM/CDM/PDS* avec au moins une *protection principale* selon les exigences du 4.4.4.6, et
- des *parties actives* avec au moins une *protection renforcée* selon les exigences du 4.4.5,

et être conçus avec la tension assignée de l'équipement connecté en série.

Un *BDM/CDM/PDS* relevant de la *protection de classe II* peut être raccordé à un conducteur de mise à la terre pour des raisons fonctionnelles ou pour l'amortissement des surtensions. Dans ce cas, le conducteur de mise à la terre fonctionnelle doit être séparé

- des *parties accessibles* ou surfaces accessibles conductrices du *BDM/CDM/PDS*, et
- des *parties actives*

avec au moins une *protection renforcée* selon les exigences du 4.4.5.

La conformité est vérifiée par l'*inspection visuelle* du 5.2.1.

Un *BDM/CDM/PDS* relevant de la *protection de classe II* doit faire l'objet d'un marquage selon 6.3.9.2.3.

4.4.6.4 Mesures de protection des *BDM/CDM/PDS* relevant de la *protection de classe III*

Les *BDM/CDM/PDS* relevant de la *protection de classe* III ne nécessitent pas de *protection principale* ou de *protection en cas de défaut* et doivent être marqués selon 6.3.9.2.4.

NOTE Les équipements relevant de la *protection de classe III* sont alimentés conformément aux mesures de protection des circuits *CTD As* (voir 4.4.2.2). Par conséquent, les équipements de *classe III* étant considérés comme sûrs au contact, il n'est pas nécessaire de prévoir d'autres mesures de protection contre les chocs électriques, toutefois, il peut être raccordé à un conducteur de mise à la terre pour des raisons fonctionnelles ou pour l'amortissement des surtensions.

4.4.6.5 Mesures de protection des circuits *CTD As* dans un BDM/CDM/*PDS* relevant de la *protection de classe I* ou de la *protection de classe II*

4.4.6.5.1 Généralités

Les *mesures de protection* doivent être assurées par une *protection renforcée* de l'une des façons suivantes:

- *double isolation* selon 4.4.5.2;
- *isolation renforcée* selon 4.4.5.3;
- *écran de protection électrique* selon 4.4.4.7 et *protection principale* selon 4.4.4.6; ou
- une combinaison de ces dispositions

utilisée en combinaison avec l'un des moyens suivants:

- limitation de tension selon 4.4.6.5.2;
- *impédance de protection* selon 4.4.5.4 comprenant une limitation d'énergie de décharge et de courant; ou
- d'autres moyens qui satisfont aux exigences de la *CTD As*.

Voir la Figure A.8, exemple 4.

La *protection renforcée* doit être totale et maintenue effective quelles que soient les conditions prévues d'utilisation du *BDM/CDM/PDS*.

4.4.6.5.2 Protection au moyen de tensions limitées

La tension entre les *parties accessibles* conductrices simultanément ne doit pas être supérieure à la *CTD As* telle que déterminée en 4.4.2.2.

Voir l’Article A.2 pour des exemples de ces mesures.

4.4.6.5.3 Dispositions en matière de raccordement aux circuits *TBTP* et aux circuits *TBTS* externes

Si un *accès* est destiné à être raccordé à un *circuit TBTP* ou *TBTS* externe dont la source de tension est supérieure à la *CTD As*,

- des mesures permettant de limiter la tension de cette *CTD As* doivent être prises (voir l’Article A.2), ou
- une *protection principale* selon 4.4.3.3 doit être prévue afin d’empêcher l’accès aux *parties actives dangereuses*.

Le raccordement des circuits *TBTP* ou *TBTS* externes à un circuit interne est admis en prenant en considération les éléments suivants:

- sans mesure: uniquement si la *CTD* de la tension des circuits *TBTP* ou des circuits *TBTS* est inférieure ou égale à la *CTD* choisie dans le Tableau 2 pour le circuit interne à l'étude;
- avec mesures: si la *CTD* de la tension des circuits *TBTP* ou des circuits *TBTS* est supérieure à la *CTD* choisie dans le Tableau 2 pour le circuit interne à l'étude.

Les *conditions de premier défaut* doivent être évaluées pendant l'analyse des défauts du 4.2 en prenant en considération au moins

- les tensions concernées dans les conditions normales de fonctionnement et les *conditions de premier défaut du BDM/CDM/PDS* ou des interconnexions,
- la possibilité d'ajout de tensions des *circuits adjacents*,
- la possibilité d'un accès aux *parties actives dangereuses*, et
- la mise à la terre, ou non, des circuits concernés.

Pour le marquage, voir 6.3.7 et 6.3.9.1.

4.4.7 *Isolation*

4.4.7.1 Facteurs d’influence

4.4.7.1.1 Généralités

Le paragraphe 4.4.7.1 fournit les exigences minimales d'*isolation*, fondées sur les principes de l’IEC 60664.

Les tolérances de fabrication doivent être prises en compte pour les distances indiquées en 4.4.7.

Le choix de l'*isolation* doit être effectué en tenant compte de l'influence des facteurs suivants:

- la *tension de fonctionnement* (voir 4.4.7.1.2);
- le degré de pollution (voir 4.4.7.1.3);
- la catégorie de surtension (OVC) (voir 4.4.7.1.4);
- le *système* de mise à la terre de l'alimentation (voir 4.4.7.1.5);
- la *tension de tenue aux chocs* et la *surtension temporaire* (voir 4.4.7.1.6);
- *tension système* en prenant en considération la mise à la terre spécifiée du système d'alimentation (voir 4.4.7.1.7);
- l'altitude, les fréquences supérieures à 30 kHz l'homogénéité du champ (voir 4.4.7.4.3;4.4.7.4.4);
- l'emplacement physique de l'*isolation*;
- le type d'*isolation* (*isolation fonctionnelle, isolation principale, isolation supplémentaire, double isolation* ou *isolation renforcée*); et
- les caractéristiques du matériau (voir 4.4.7.5.1, 4.4.7.8.2,4.4.7.8.4).

L'*isolation* doit être vérifiée conformément aux essais applicables de 5.2.2.1, 5.2.3.2, 5.2.3.4 et 5.2.3.5.

Pour le *PDS intégré*, le *système d'isolation* du moteur doit satisfaire aux exigences de la partie appropriée de la série IEC 60034. Les *BDM*/CDM doivent satisfaire aux exigences du 4.4.7.

NOTE Aux États-Unis, le *système d'isolation* du moteur doit satisfaire aux exigences de la partie appropriée de l'UL 1004.

Les *distances d'isolement* et les *lignes de fuite* au niveau des *composants* et des sous-ensembles, qui sont destinés à être remplacés, doivent être déterminées en tenant compte des dimensions les plus défavorables.

EXEMPLE Fusibles, porte-fusibles, bornes pour câblage et cosses.

4.4.7.1.2 *Tension de fonctionnement*

Pour la conception du *système d'isolation* selon 4.4.7, la *tension de fonctionnement*, la crête répétitive, la valeur efficace ou le courant continu doit être déterminé par calcul, par simulation ou par des essais en tenant compte de la tension à l'intérieur des circuits, par rapport aux *circuits adjacents* et à la terre.

Pour des recommandations, voir l'Article A.5.

Pour l'essai, voir 5.2.3.14.

4.4.7.1.3 Degré de pollution

L'*isolation*, particulièrement lorsqu'elle est réalisée par des *distances d'isolement* et des *lignes de fuite*, est affectée par la pollution qui apparaît pendant la *durée de vie prévue* du *BDM/CDM/PDS*. Les conditions microenvironnementales concernant l'*isolation* doivent être appliquées selon le Tableau 5.

Tableau 5 – Définitions des degrés de pollution

Degré de pollution	Description
1	Pas de pollution ou apparition uniquement d'une pollution sèche non conductrice. La pollution n'a pas d'influence.
2	Normalement, il n'y a apparition que d'une pollution non conductrice. Occasionnellement, toutefois, une conductivité temporaire causée par la condensation doit être envisagée. Cette condensation (temporaire) peut se former pendant des cycles de fonctionnement marche-arrêt du *BDM/CDM/PDS*.
3	Une pollution conductrice ou une pollution sèche non conductrice apparaît qui devient conductrice par de la condensation qui doit être envisagée.
4	La pollution génère une conductivité persistante causée, par exemple, par de la poussière conductrice, de l'eau ou de la neige.
NOTE La définition des degrés de pollution du Tableau 5 est conforme à celle de l'IEC 60664-1:2020; 4.5.2	

Le degré de pollution doit être déterminé en fonction des conditions de service environnementales pour lesquelles le produit est spécifié. Voir le Tableau 20 pour le choix du degré de pollution en fonction de la classification environnementale de l'*installation*.

L'*isolation* peut être déterminée en fonction du degré de pollution 2 si l'une des conditions suivantes a), b) ou c) s'applique:

a) des instructions sont fournies avec le *BDM/CDM/PDS* indiquant qu'il doit être installé dans un environnement de degré de pollution 2;

b) l'application spécifique où s'effectue l'*installation* du *BDM/CDM/PDS* est connue pour être un environnement de degré de pollution 2; ou

c) l'*enveloppe* du *BDM/CDM/PDS* ou les revêtements appliqués dans le *BDM/CDM/PDS* selon 4.4.7.8.4.3 ou 4.4.7.8.5 fournissent une protection adéquate pour les degrés de pollution 3 et 4 (condensation et pollution conductrice).

Lorsqu'une condensation interne ou une accumulation d'eau se produit pendant le fonctionnement normal ou la maintenance, des mesures doivent être prises pour empêcher la dégradation de l'*isolation*. Voir 4.12.8.

De plus amples informations relatives à la réduction du degré de pollution sont fournies à l'Annex B.

Le fabricant de *BDM/CDM/PDS* doit indiquer dans la documentation le degré de pollution pour lequel le *BDM/CDM/PDS* a été conçu.

Pour le marquage, voir 6.3.3.

Si le fonctionnement dans un environnement présentant un degré de pollution 4 est exigé, la protection contre la pollution conductrice doit être assurée au moyen d'une *enveloppe* adaptée.

Pour le degré de pollution 4, les dimensions des *lignes de fuite* ne peuvent pas être spécifiées. Pour le degré de pollution 3, la surface de l'*isolation* peut être conçue pour éviter tout chemin continu de pollution conductrice, par exemple au moyen de nervures et de rainures. L'Annex D donne des informations relatives à l'évaluation des *distances d'isolement* et des *lignes de fuite*.

4.4.7.1.4 Catégorie de surtension (OVC)

Le concept de catégories de surtension (sur la base de l'IEC 60364-4-44 et de l'IEC 60664-1) est utilisé pour les *BDM/CDM/PDS* mis sous tension à partir du *réseau* et concerne le niveau de protection contre les surtensions prévu.

Quatre catégories sont concernées.

- Les équipements relevant de la catégorie de surtension IV (OVC IV) sont utilisés à l'origine de l'*installation*.

  EXEMPLE 1 Multimètres, appareils de protection contre les *surintensités* au primaire connectés directement à des lignes extérieures aériennes.

- Les équipements relevant de la catégorie de surtension III (OVC III) sont utilisés dans des *installations* fixes (en aval du tableau de distribution principal inclus).

  EXEMPLE 2 Commutateurs dans l'*installation* fixe et équipements à usage industriel connectés en permanence à l'*installation* fixe.

- Les équipements relevant de la catégorie de surtension II (OVC II) sont les équipements consommateurs d'énergie qui doivent être alimentés par l'*installation* fixe.

  EXEMPLE 3 Appareils, outils portatifs et autres appareils domestiques ou similaires.

  Si ce type d'équipements fait l'objet d'exigences particulières en ce qui concerne la fiabilité et à la disponibilité, la catégorie de surtension III s'applique.

- Les équipements relevant de la catégorie de surtension I (OVC I) sont ceux destinés à être raccordés aux circuits dans lesquels des mesures sont prises pour limiter les surtensions transitoires à un faible niveau approprié.

  EXEMPLE 4 Équipements contenant ces circuits électroniques protégés à ce niveau.

NOTE À moins que les circuits ne soient conçus pour tenir compte des *surtensions temporaires*, les équipements relevant de la *catégorie de surtension I* ne peuvent pas être raccordés directement au *réseau*.

Les mesures de réduction de la *tension de tenue aux chocs* doivent assurer que les *surtensions temporaires* susceptibles de se produire sont suffisamment limitées, doivent faire en sorte que leur valeur de crête ne dépasse pas la *tension assignée de tenue aux chocs* adéquate du Tableau 6 ou du Tableau 7 et doivent satisfaire aux exigences du 4.4.7.2.3, 4.4.7.2.4 et 4.4.7.3 selon le cas.

L'Annex I donne des exemples de catégories de surtension pour les exigences d'*isolation*.

Pour les *BDM/CDM/PDS* et les circuits destinés à être alimentés par une *alimentation non raccordée directement au réseau*, la catégorie de surtension appropriée doit être déterminée comme exigé par l'application en fonction du contrôle des surtensions fourni sur l'alimentation des *BDM/CDM/PDS* ou du circuit. Voir 4.4.7.2.4.

4.4.7.1.5 *Système* de mise à la terre de l'alimentation

Les trois principaux types de *systèmes* de mise à la terre de suivants sont décrits dans l'IEC 60364-1.

- *Système* TN: possède un point directement à la terre, les *parties accessibles* conductrices de l'*installation* étant reliées à ce point par des *conducteurs de mise à la terre de protection.* Trois types de *systèmes* TN, les systèmes TN-C, TN-S et TN-C-S sont définis suivant la disposition des conducteurs de neutre et des *conducteurs de mise à la terre de protection*. Un *système* TN "corner-earthed" ou "high-leg delta" est un *système* TN avec un point à la terre.
- *Système* TT: possède un point directement mis à la terre, les *parties accessibles* conductrices de l'*installation* étant reliées à des prises de terre électriquement distinctes de la prise de terre du *système* d'alimentation. Un *système* TT "corner-earthed" ou "high-leg delta" est un *système* TT avec un point à la terre.

  NOTE 1 Aux États-Unis et au Canada, l'utilisation du système TT ne s'applique pas.

- *Système* IT: toutes les *parties actives* sont isolées de la terre ou un point est relié à la terre par l'intermédiaire d'une impédance, les *parties accessibles* conductrices de l'*installation* étant raccordées indépendamment ou collectivement au *système* de mise à la terre.

NOTE 2 "Un point" est en général un point neutre ou une phase, mais pas forcément.

NOTE 3 Pour de plus amples informations relatives aux concepts de *système* de mise à la terre (TN-C, TN-S et TN-C-S, par exemple), voir l'IEC 60364-1:2005, Article 312.

NOTE 4 Deux cas de *systèmes* connectés en triangle avec un point directement mis à la terre sont les *systèmes* "corner-earthed" et les *systèmes* "high-leg delta". Dans un système "corner-earthed", une phase est directement mise à la terre. Dans un système "high-leg delta", l'enroulement d'un transformateur relié en triangle est à prise médiane, laquelle est directement reliée à la terre.

Dans un *BDM/CDM/PDS* conçu pour fonctionner sur un *système* "corner-earthed" ou "high-leg delta",

- l'*isolation* entre les phases du *réseau*, y compris la phase mise à la terre, peut être conçue pour être une *isolation fonctionnelle* conformément à 4.4.7.3, et
- les circuits du *BDM/CDM/PDS* directement connectés à une phase d'un *système* "corner-earthed" ou "high-leg delta" doivent être séparés des parties mises à la terre par au moins une *isolation principale*.

Pour le marquage, voir 6.2.1.4 e).

Les systèmes de mise à la terre de l'alimentation choisis et spécifiés par le fabricant en 6.2.1.4 e) sont utilisés comme entrées pour la détermination de la tension système du 4.4.7.1.7.

4.4.7.1.6 Détermination de la *tension de tenue aux chocs* et de la *surtension temporaire*

Le Tableau 6 et le Tableau 7 utilisent la *tension système* (voir 4.4.7.1.7) et la catégorie de surtension (voir 4.4.7.1.4) du circuit à l'étude pour déterminer la *tension de tenue aux chocs*.

La *tension système* sert également à déterminer la *surtension temporaire*.

Tableau 6 – *Tension de tenue aux chocs* et *surtension temporaire* en fonction de la *tension système* des circuits *basse tension*

Colonne 1	2	3	4	5	6
Tension système **(voir 4.4.7.1.7)** V	***Tension de tenue aux chocs*** V				***Surtension temporaire*** [a] V
	Catégorie de surtension				
Courant alternatif	**I**	**II**	**III**	**IV**	**Valeur crête/ valeur efficace**
≤ 50	330	500	800	1 500	1 770/1 250
≤ 100	500	800	1 500	2 500	1 840/1 300
≤ 150	800	1 500	2 500	4 000	1 910/1 350
≤ 300	1 500	2 500	4 000	6 000	2 120/1 500
≤ 600	2 500	4 000	6 000	8 000	2 550/1 800
≤ 1 000	4 000	6 000	8 000	12 000	3 110/2 200

L'interpolation de la *tension système* n'est pas admise dans le cadre de la détermination de la *tension de tenue aux chocs* pour le *réseau*. L'interpolation de la *tension système* est admise dans le cadre de la détermination de la *surtension temporaire* pour le *réseau*.

L'interpolation de la *tension système* n'est pas admise dans le cadre de la détermination de la *tension de tenue aux chocs* pour l'*alimentation non raccordée directement au réseau*. L'interpolation de la *tension système* est admise dans le cadre de la détermination de la *surtension temporaire* pour l'*alimentation non raccordée directement au réseau*.

[a] Les valeurs efficaces sont issues de la formule (1 200 V + *tension système*) de l'IEC 60664-1:2020.

Tableau 7 – *Tension de tenue aux chocs* et *surtension temporaire* en fonction de la *tension système* des circuits haute tension

Colonne 1	2	3	4	5	6
Tension système **(4.4.7.1.7)** V	***Tension de tenue aux chocs*** V				***Surtension temporaire*** V
	Catégorie de surtension				
Courant alternatif	**I**	**II**	**III**	**IV**	**Valeur crête/ valeur efficace**
> 1 000	4 000	6 000	8 000	12 000	4 250/3 000
3 600	9 000	16 000	20 000	40 000	14 150/10 000
7 200	17 500	29 000	40 000	60 000	28 300/20 000
12 000	29 000	42 500	60 000	75 000	39 600/28 000
17 500	40 000	55 000	75 000	95 000	53 750/38 000
24 000	52 000	75 000	95 000	125 000	70 700/50 000
36 000	75 000	95 000	125 000	145 000	99 000/70 000

SOURCE: IEC 62477-2:2018, Tableau 101.

L'interpolation est admise.

4.4.7.1.7 Détermination de la *tension système*

4.4.7.1.7.1 Pour le *réseau*

La tension système dépend du *système* de mise à la terre de l'alimentation du 4.4.7.1.5, qui sont choisies et spécifiées par le fabricant en 6.2.1.4 e). Pour les *BDM/CDM/PDS* alimentés par un *réseau* en courant alternatif, la *tension système* est

a) dans le Tableau 6 pour la *basse tension*:
   - dans un *système* TN mis à la terre en point neutre et dans les *systèmes* TT, la valeur efficace de la tension assignée entre une phase et la terre;
   - dans les *systèmes* TN "corner-earthed" ou "high-leg delta" et les *systèmes* TT, la valeur efficace de la tension assignée entre les phases;
   - dans les *systèmes* IT triphasés:
     – pour la détermination de la *tension de tenue aux chocs*, la valeur efficace de la tension nominale entre une phase et un point neutre artificiel (un raccordement imaginaire entre impédances d'égale valeur et chaque phase);

       NOTE 1 Pour la plupart des systèmes, cela équivaut à diviser la tension entre phases par √3.

       NOTE 2 La phase à un point neutre artificiel peut être acceptée pour des *systèmes* correctement équilibrés. Dans les *conditions de premier défaut*, la *tension système* passe temporairement à une tension entre phases, mais dans cette *condition de premier défaut*, il est admis que la *tension de tenue aux chocs* diminue d'un cran conformément au Tableau 6.

     – pour la détermination de la *surtension temporaire*, la valeur efficace de la tension assignée entre les phases;
   - dans un *système* IT monophasé: la valeur efficace de la tension assignée entre les conducteurs d'alimentation.

b) dans le Tableau 7 pour les circuits, haute tension la valeur efficace de la tension assignée entre les phases.

Si la tension d'alimentation est redressée en courant continu, et déduite du *réseau* en courant alternatif, la *tension système* est la valeur efficace du courant alternatif de la source avant le redressement, en tenant compte du *système* de mise à la terre de l'alimentation.

Pour les *BDM/CDM* équipés de redresseurs en pont (12 alternances, 18 alternances, par exemple) connectés en série au niveau de la sortie, la *tension système* pour la détermination des *tensions de tenue aux chocs* est la valeur efficace la plus élevée de la tension alternative avant le redressement au niveau de l'un des redresseurs en pont, en tenant compte du *système* de mise à la terre de l'alimentation (*système* TN, *système* TT ou *système* IT).

Les tensions générées dans le *BDM/CDM/PDS* par les secondaires des transformateurs fournissant une isolation galvanique à partir du *réseau* sont considérées comme des *tensions système* pour la détermination des tensions de tenue aux chocs.

NOTE 3 De plus amples informations sont données dans l'IEC 61800-2:2021, Annexe A.

4.4.7.1.7.2 Pour l'*alimentation non raccordée directement au réseau*

Pour les *BDM/CDM/PDS* alimentés par une *alimentation non raccordée directement au réseau* en courant alternatif ou en courant continu, la *tension système* est la valeur efficace de la tension d'alimentation entre les phases.

Si une tension d'alimentation en courant continu n'est pas fournie par un *réseau* en courant alternatif, la détermination de la *tension système* et tout le *système d'isolation* doivent satisfaire aux exigences de l'IEC 62477-1:2022 et de l'IEC 62477-2:2018.

Pour le marquage, voir 6.2.1.3 a).

4.4.7.1.8 *Isolation* par pontage des *composants*

Les *composants* pontant l'*isolation principale*, l'*isolation supplémentaire* ou l'*isolation renforcée* doivent satisfaire aux exigences du niveau d'*isolation* qu'ils pontent. Voir 4.13 pour les exigences de *composants*.

4.4.7.2 *Isolation* par rapport à l'*environnement*

4.4.7.2.1 Généralités

L'*isolation* correspondant à l'*isolation principale*, à l'*isolation supplémentaire* et à l'*isolation renforcée* entre un circuit et son *environnement* en 4.4.7.2.3 et 4.4.7.2.4 doit être conçue selon les exigences les plus sévères en matière de

- *tension de tenue aux chocs*,
- *surtension temporaire*, et de
- *tension de fonctionnement* du circuit.

Pour les *lignes de fuite*, la valeur efficace de la *tension de fonctionnement* est utilisée comme cela est décrit en 4.4.7.5.

Pour les *distances d'isolement* et l'*isolation solide*, la *tension de tenue aux chocs*, la *surtension temporaire* ou la valeur de crête répétitive de la *tension de fonctionnement* est utilisée comme cela est décrit en 4.4.7.2.3, 4.4.7.2.4 et en 4.4.7.2.5.

NOTE 1 Des *tensions de fonctionnement* combinant des valeurs de crête en courant alternatif, en courant continu ou répétitive peuvent être observées sur la liaison en tension continue d'un convertisseur à source de tension indirecte ou peuvent être des oscillations amorties d'un circuit écrêteur de thyristor ou encore des tensions internes d'une alimentation à découpage. Pour plus d'informations, voir l'Article A.5.

NOTE 2 La *tension de tenue aux chocs* et la *surtension temporaire* dépendent de la *tension système* du circuit, et la *tension de tenue aux chocs* dépend également de la catégorie de surtension, comme cela est indiqué dans le Tableau 6 et dans le Tableau 7.

Si les circuits de la *CTD As* ou de la *CTD B* sont alimentés par le *réseau* par l'intermédiaire d'un transformateur assurant une isolation galvanique et fonctionnant à au moins 10 kHz, l'*isolation* entre le circuit et l'*environnement* peut être déterminée en fonction de la *tension de fonctionnement* du circuit.

Dans ce cas, l'aptitude du transformateur à réduire les *tensions de tenue aux chocs* à des valeurs inférieures à la *tension de tenue aux chocs* associée à la *tension de fonctionnement* déterminée à partir du Tableau 6 ou du Tableau 7 applicable doit être démontrée par essai (voir 5.2.3.2), simulation ou calcul.

NOTE 3 L'aptitude d'un transformateur haute fréquence à réduire les *tensions de tenue aux chocs* provient d'une très faible capacité répartie de l'*isolation* galvanique comparée à la capacité de mise à la terre classique dans le circuit *CTD As* ou *CTD B*.

4.4.7.2.2 Surveillance du *SPD*

Si le fabricant du *BDM/CDM* intègre un dispositif de protection externe à son produit aux fins de la réduction de la catégorie de surtension, ce dispositif doit comporter un circuit de surveillance comme l'exigent les articles 4.4.7.2.3 ou 4.4.7.2.4 qui permette au *BDM/CDM* de créer une indication lorsque le dispositif est endommagé par une surtension. Si le SPD est interne à un *BDM/CDM*, l'essai du 5.2.3.15 s'applique.

L'essai de surveillance du *SPD* interne décrit ci-dessus n'est pas exigé sur les circuits du *SPD* qui ne participent pas à la réduction de la catégorie de surtension pour réduire les *distances d'isolement*.

La conformité est déterminée par l'*inspection visuelle* du 5.2.1 ou l'essai du 5.2.3.15 selon le cas.

4.4.7.2.3 Circuits connectés directement au *réseau*

L'*isolation* entre l'*environnement* et les circuits qui sont connectés directement au *réseau* doit être conçue en fonction de la *tension de tenue aux chocs*, de la *surtension temporaire* ou de la *tension de fonctionnement*, la tension retenue étant celle qui donne l'exigence la plus sévère.

Cette *isolation* est évaluée normalement pour résister aux tensions de choc de catégorie de surtension III, à une exception: la catégorie de surtension IV doit être utilisée quand le *BDM/CDM/PDS* est connecté à la source de l'*installation* de *réseau*. La catégorie de surtension II peut être utilisée pour les équipements enfichables sans exigence particulière de fiabilité.

Si des mesures sont utilisées pour réduire les tensions de choc de catégorie de surtension IV aux valeurs de la catégorie III ou de la catégorie III à la catégorie II, l'*isolation principale* ou l'*isolation supplémentaire* peut être conçue pour ces valeurs réduites.

Les exigences de *double isolation* ou d'*isolation renforcée* ne doivent pas être réduites à des valeurs inférieures à celles exigées pour l'*isolation principale* prévues pour résister à des tensions de choc en l'absence de ces mesures.

Si les dispositifs utilisés à cet effet peuvent être endommagés par des surtensions ou des tensions de choc répétées, diminuant ainsi leur possibilité de réduire les tensions de choc, ils doivent être surveillés et une information sur leur état doit être fournie selon 4.4.7.2.2.

Si le *BDM/CDM/PDS* est conçu pour une *tension de tenue aux chocs* réduite, le fabricant du *BDM/CDM/PDS* doit prendre des mesures permettant de réduire la surtension à l'intérieur du *BDM/CDM/PDS* ou des informations doivent être données dans le manuel d'utilisation concernant la sélection appropriée des parafoudres à installer dans l'*installation* fixe. La tension d'écrêtage des SPD ne doit pas être supérieure à la *tension de tenue aux chocs* spécifiée pour la catégorie de surtension du Tableau 6 ou du Tableau 7. Pour choisir de manière pertinente les SPD dans l'*installation* fixe ou dans le *BDM/CDM/PDS*, il est nécessaire de prendre en considération des facteurs tels que la tension maximale de régime permanent du SPD en fonction de la mise à la terre du système d'alimentation, la connexion à la terre, l'énergie de décharge et le comportement en cas de défaillance de *surtension temporaire*.

Un plan de maintenance préventive est une alternative à la surveillance, tant que la réduction de surtension ne varie pas.

Pour le marquage, voir 6.3.9.6.4 et 6.5.1.

NOTE 1 Si une protection inhérente ou un *SPD* interne au *PDS* ou faisant partie intégrante de l'*installation* est utilisé pour réduire la valeur de la *tension de tenue aux chocs,* voir l'IEC 61643-12 pour des informations relatives au choix et à l'utilisation de ce type de *SPD* pour les *systèmes basse tension*.

NOTE 2 Les circuits connectés au *réseau* par l'intermédiaire d'*impédances de protection* selon 4.4.5.4, ne sont pas considérés comme étant connectés directement au *réseau*.

Pour de plus amples informations relatives à la réduction des catégories de surtension, voir l'Annex I.

4.4.7.2.4 Circuits connectés à l'*alimentation non raccordée directement au réseau*

L'*isolation* entre l'*environnement* et les circuits alimentés par une *alimentation non raccordée directement au réseau* doit être conçue selon les exigences les plus sévères en matière de

- *tension de tenue aux chocs* déterminée dans le Tableau 6 à l'aide de la *tension système*,
- *surtension temporaire*, si elle est réputée exister compte tenu de la nature de l'alimentation, et de
- *tension de fonctionnement*.

Ces valeurs sont utilisées pour alimenter le Tableau 8 pour le calcul des *distances d'isolement*.

Cette *isolation* est évaluée normalement pour résister aux tensions de choc de catégorie de surtension II, à une exception: la catégorie de surtension III doit être utilisée quand le *BDM/CDM/PDS* est connecté à la source de l'*installation* d'*alimentation non raccordée directement au réseau*.

NOTE 1 La catégorie de surtension des *alimentations non raccordées directement au réseau* ne varie pas entre les équipements *connectés en permanence* dans des *installation*s fixes et les équipements non *connectés en permanence* raccordés à l'*installation* fixe.

Les *accès* connectés aux circuits de la *CTD As* ou de la *CTD B* pour le mesurage et la commande de processus doivent être considérés comme des *alimentations non raccordées directement au réseau*.

Si des mesures sont utilisées pour réduire les tensions de choc de catégorie de surtension III aux valeurs de la catégorie II ou de la catégorie II à la catégorie I, l'*isolation principale* ou l'*isolation supplémentaire* peut être conçue pour cette valeur réduite.

Les exigences de *double isolation* ou d'*isolation renforcée* ne doivent pas être réduites à des valeurs inférieures à celles exigées pour l'*isolation principale* prévues pour résister à des tensions de choc en l'absence de ces mesures.

Si les dispositifs utilisés à cet effet peuvent être endommagés par des surtensions ou des tensions de choc répétées, diminuant ainsi leur possibilité de réduire les tensions de choc, ils doivent être surveillés et une information sur leur état doit être fournie selon 4.4.7.2.2.

Pour le marquage, voir 6.3.9.6.4 et 6.5.1.

NOTE 2 La *tension de tenue aux chocs* déterminée reposant sur la *tension système* peut être réduite au moyen d'une protection inhérente ou d'un *SPD* interne dans le *PDS* ou faisant partie intégrante de l'*installation*. L'IEC 61643-12 donne des informations relatives au choix et à l'utilisation de ce type de *SPD*.

4.4.7.2.5 *Isolation* entre les circuits

L'*isolation* entre deux circuits doit être conçue en fonction du circuit ayant les exigences les plus sévères.

Pour la conception de l'*isolation principale* et de l'*isolation renforcée* entre des circuits, l'*isolation* doit être conçue selon les exigences les plus sévères de a) ou b):

a) le circuit ayant les exigences les plus sévères; ou
b) la *tension de fonctionnement* entre les circuits.

4.4.7.3 *Isolation fonctionnelle*

Si la défaillance de l'*isolation fonctionnelle* n'engendre pas de danger couvert par le présent document (électrique, thermique, feu), le dimensionnement de l'*isolation fonctionnelle* ne fait l'objet d'aucune exigence particulière. Dans les autres cas, les exigences suivantes s'appliquent.

Les essais ne sont pas nécessaires, sauf si l'analyse du circuit exigée en 4.2 indique que la défaillance de l'*isolation* peut être dangereuse.

Pour des parties ou des circuits qui sont affectés de manière significative par des transitoires externes, l'*isolation fonctionnelle* doit être conçue en fonction de la *tension de tenue aux chocs* de la catégorie de surtension II, mais la catégorie de surtension III doit être utilisée lorsque le *BDM/CDM/PDS* est connecté à la source de l'*installation*.

Quand des mesures sont utilisées pour réduire les surtensions transitoires dans le circuit de catégorie III à des valeurs de catégorie II ou de catégorie II à la catégorie I, l'*isolation fonctionnelle* peut être conçue pour les valeurs réduites.

Lorsque les caractéristiques du circuit peuvent être démontrées par des essais (voir 5.2.3.2) pour réduire les *tensions de tenue aux chocs*, l'*isolation fonctionnelle* peut être conçue pour la *tension de tenue aux chocs* la plus élevée se produisant dans le circuit pendant les essais.

Pour des parties ou des circuits qui ne sont pas affectés de manière significative par des transitoires externes, une *isolation fonctionnelle* doit être conçue en fonction de la *tension de fonctionnement* appliquée à l'*isolation*.

Les exigences du 4.4.7.7 s'appliquent.

4.4.7.4 *Distance d'isolement*

4.4.7.4.1 Généralités

Les *distances d'isolement* doivent être déterminées pour l'*isolation fonctionnelle, l'isolation principale* ou l'*isolation supplémentaire* directement à partir du Tableau 8.

Pour des recommandations, voir l'Article O.1 et l'organigramme représenté à la Figure O.1.

NOTE Les normes couvrant les applications finales dans lesquelles le BDM/CDM est utilisé en tant que *composant* peuvent demander des exigences plus sévères en matière de *distance d'isolement* (l'IEC 61439-1, l'IEC 60204-1, l'UL 508A, par exemple).

Voir l'Annex D pour des exemples d'évaluation de la *distance d'isolement*.

Tableau 8 – *Distance d'isolement* pour l'*isolation fonctionnelle*, l'*isolation principale* ou l'*isolation supplémentaire n*

<table>
<tr><th>Colonne 1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th></tr>
<tr><td>Tension de tenue aux chocs [d]
(du Tableau 6 ou du Tableau 7)
V</td><td>Surtension temporaire [f]
(crête)[h]
(du Tableau 6 ou du Tableau 7)
V</td><td>Tension de fonctionnement [f]
(crête répétitive) [a]
V</td><td colspan="4">Distances d'isolement minimales jusqu'à 2 000 m au-dessus du niveau de la mer
mm</td></tr>
<tr><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td colspan="4">Degré de pollution</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td></tr>
<tr><td>N/A</td><td>≤ 110</td><td>≤ 88</td><td>0,01</td><td rowspan="5">0,2 [b c]</td><td rowspan="6">0,8 [c]</td><td rowspan="7">1,6 [c]</td></tr>
<tr><td>N/A</td><td>225</td><td>180</td><td>0,01</td></tr>
<tr><td>330</td><td>330 [e]</td><td>260 [e]</td><td>0,01</td></tr>
<tr><td>500</td><td>500 [e]</td><td>400 [e]</td><td>0,04</td></tr>
<tr><td>800</td><td>710 [e]</td><td>560 [e]</td><td>0,10</td></tr>
<tr><td>1 500</td><td>1 270 [e]</td><td>1 010 [e]</td><td>0,5</td><td>0,5</td></tr>
<tr><td>2 500</td><td>2 220 [e]</td><td>2 000 [e]</td><td>1,5</td><td>1,5</td><td>1,5</td></tr>
<tr><td>4 000</td><td>3 430 [e]</td><td>3 090 [e]</td><td colspan="4">3,0</td></tr>
<tr><td>6 000</td><td>4 890 [e]</td><td>4 410 [e]</td><td colspan="4">5,5</td></tr>
<tr><td>8 000</td><td>6 060 [e]</td><td>5 460 [e]</td><td colspan="4">8,0</td></tr>
<tr><td>12 000</td><td>9 500 [e]</td><td>8 550 [e]</td><td colspan="4">14</td></tr>
<tr><td>20 000</td><td>15 000</td><td>13 500</td><td colspan="4">25</td></tr>
</table>

Colonne 1	2	3	4	5	6	7
Tension de tenue aux chocs [d] **(du Tableau 6 ou du Tableau 7)**	***Surtension temporaire*** [f] **(crête)**[h] **(du Tableau 6 ou du Tableau 7)**	***Tension de fonctionnement*** [f] **(crête répétitive)** [a]	***Distances d'isolement* minimales jusqu'à 2 000 m au-dessus du niveau de la mer**			
40 000	32 300	29 000	60			
60 000	45 700	41 100	90			
75 000	59 700 [g]	53 700 [g]	120			
95 000	78 800 [g]	70 900 [g]	160			
125 000	107 000 [g]	96 000 [g]	220			
145 000	130 000 [g]	117 000 [g]	270			

NOTE Pour la détermination de l'*isolation renforcée* et de la *double isolation*, voir 4.4.7.4.2.

[a] Cette tension est égale à environ 0,8 fois la tension exigée pour couper la *distance d'isolement* associée pour les *tensions de tenue aux chocs* inférieures à 2 500 V et 0,9 fois la tension exigée pour couper la distance d'isolement pour les *tensions de tenue aux chocs* supérieures à 2 500 V.

[b] Pour les cartes de circuit imprimé, les valeurs du degré de pollution 1 s'appliquent, sauf qu'elles ne doivent pas être inférieures à 0,04 mm.

[c] Les *distances d'isolement* minimales indiquées pour le degré de pollution 2, le degré de pollution 3 et le degré de pollution 4 reposent sur des caractéristiques de tenue réduites de la *distance d'isolement* associée dans des conditions humides (voir l'IEC TR 63040:2016).

[d] L'interpolation est admise pour l'*alimentation non raccordée directement au réseau*, mais pas pour le *réseau*. Les *distances d'isolement* correspondant à une tension de tenue aux chocs sont déduites de l'IEC 60664-1:2020, Tableau F.2.

[e] Les *distances d'isolement* correspondant à la *surtension temporaire* et à la *tension de fonctionnement* sont déduites de l'IEC 60664-1:2020, Tableau F.8.

[f] L'interpolation est admise lorsque la *distance d'isolement* est déterminée à partir de la *surtension temporaire* et de la *tension de fonctionnement*.

[g] Les valeurs sont extrapolées à partir de l'IEC 60664-1:2020.

[h] Uniquement pertinent pour déterminer l'*isolation* entre l'*environnement* et les circuits.

NOTE Si les *distances d'isolement* sont soumises à des contraintes avec des tensions de crête en régime établi de 2,5 kV (crête) et supérieures, le dimensionnement selon les valeurs de claquage du Tableau 8 ne peut pas assurer un fonctionnement sans effet couronne (décharges partielles), en particulier pour les champs hétérogènes. Pour assurer un fonctionnement sans effet couronne, il est soit possible d'utiliser des *distances d'isolement* plus importantes comme cela est indiqué dans le Tableau F.9 de l'IEC 60664-1:2020, soit d'améliorer la distribution de champ.

La conformité doit être vérifiée selon 5.2.2.1.

4.4.7.4.2 *Isolation renforcée*

Les *distances d'isolement* pour l'*isolation renforcée* doivent être dimensionnées de manière à résister aux valeurs suivantes exigées pour l'*isolation principale* du Tableau 8:

a) pour les *BDM/CDM/PDS basse tension*:
   - la tension de tenue aux chocs immédiatement supérieure dans la colonne 1 du Tableau 8;
   - à 1,6 fois la *surtension temporaire* de crête; ou
   - à 1,6 fois la *tension de fonctionnement* de crête répétitive;

b) pour les *BDM/CDM/PDS haute tension*:

   la valeur correspondant à 1,6 fois la *tension de tenue aux chocs*, la *surtension temporaire* ou la *tension de fonctionnement.*

4.4.7.4.3 *Distance d'isolement* pour une utilisation au-dessus de 2 000 m et/ou au-dessus de 30 kHz

Les *distances d'isolement* pour l'*isolation fonctionnelle, l'isolation principale* ou l'*isolation supplémentaire* et l'*isolation renforcée* pour une utilisation à des altitudes comprises entre 2 000 m et 20 000 m doivent être calculées en utilisant un facteur de correction selon l'IEC 60664-1:2020, Tableau A.2, qui est reproduit dans le Tableau E.1.

Dans le cas de la *tension de fonctionnement* de fréquence fondamentale supérieure à 30 kHz,

- les *distances d'isolement* pour l'*isolation fonctionnelle*, l'*isolation principale* ou l'isolation supplémentaire et l'isolation renforcée dues à la *tension de fonctionnement* doivent être augmentées selon les exigences de l’Annex F, et
- les *distances d'isolement* dues à la tension de tenue aux chocs et à la *surtension temporaire* sont toujours déterminées selon 4.4.7.4.

4.4.7.4.4 Homogénéité du champ électrique

Les dimensions du Tableau 8 correspondent aux exigences d’une distribution non homogène du champ électrique à travers la *distance d'isolement*, qui est la condition normale rencontrée en pratique. Si une distribution de champ électrique plus homogène est réputée exister, la *distance d'isolement* pour l'*isolation principale* ou l'*isolation supplémentaire* peut être réduite à une valeur inférieure à celle exigée dans le Tableau F.2 de l'IEC 60664-1:2020 (Cas B). Dans ce cas, l'essai de *tension de tenue aux chocs* 5.2.3.2 doit être réalisé dans les *distances d'isolement* à l'étude.

Si les *tensions de fonctionnement* (crête répétitive) ou les *surtensions temporaires* selon le Tableau 8 sont utilisées pour le dimensionnement des *distances d'isolement*, et si ces *distances d'isolement* sont inférieures aux valeurs du Tableau 8, alors l'essai de tension alternative et continue du 5.2.3.4 doit être utilisé.

Pendant l'essai de *tension de tenue aux chocs* et l'essai de tension alternative et continue, toutes les couches d'*isolation* qui ne satisfont pas au moins l'*isolation principale* doivent être retirées.

Les *distances d’isolement* pour l’*isolation renforcée* ne doivent pas être réduites pour les champs homogènes.

La conformité doit être vérifiée selon 5.2.2.1.

4.4.7.4.5 *Distance d'isolement* avec des *enveloppes* conductrices

La *distance d'isolement* entre une *partie active dangereuse* non isolée et les parois d'une *enveloppe* métallique doit être conforme au 4.4.7.4.

Après les essais de flexion, la *distance d’isolement* entre une *partie active dangereuse* non isolée et les parois d'une *enveloppe* métallique doit être conforme aux exigences de *distances d’isolement* pour l'*isolation principale* du 4.4.7.4.

NOTE La déviation de l’*enveloppe* est considérée comme une *condition de premier défaut*.

Si la *distance d'isolement* de conception est au moins égale à 12,7 mm et si la *distance d'isolement* exigée par le Tableau 8 ne dépasse pas 8 mm, les essais de flexion peuvent ne pas être effectués.

La conformité est vérifiée par l'*inspection visuelle* du 5.2.1 et par l'essai du 5.2.2.4.2.

4.4.7.5 *Lignes de fuite*

4.4.7.5.1 Généralités

Les *lignes de fuite* doivent être suffisamment importantes pour parer à une dégradation à long terme de la surface des isolants solides.

Pour des recommandations, voir l'Article O.2 et l'organigramme représenté à la Figure O.2.

Voir l'Annex D pour des exemples d'évaluation des *lignes de fuite*.

4.4.7.5.2 Groupes de matériau isolant

Les matériaux isolants sont classés en quatre groupes selon le Tableau 9, en fonction de leur indice de résistance au cheminement (IRC) et de la catégorie de niveau de performances (CNP).

Tableau 9 – Classification des matériaux isolants

Groupe de matériau isolant	IEC [a]/CSA [b]	CNI [c]
Groupe de matériau isolant I	IRC ≥ 600	0
Groupe de matériau isolant II	600 > IRC ≥ 400	≤ 1
Groupe de matériau isolant IIIa	400 > IRC ≥ 175	≤ 3
Groupe de matériau isolant IIIb	175 > IRC ≥ 100	≤ 4

NOTE 1 L'IRC selon l'IEC 60112, la CSA C22.2 N° 0.17 et l'IRC CNP selon l'UL 746A donnent un niveau comparable de sécurité selon la pratique.

NOTE 2 Certaines fiches techniques de matériau ou de *composant* peuvent spécifier un indice de tenue au cheminement (ITC) conforme à l'IEC 60112. Pour les besoins du présent document, l'ITC selon l'IEC 60112 est considéré comme étant équivalent à l'IRC de l'IEC 60112.

[a] IRC (indice de résistance au cheminement) soumis à l'essai selon l'IEC 60112:2020, 6.2.

[b] IRC (indice de résistance au cheminement) soumis à l'essai selon la CSA C22.2 No. 0.17.

[c] CNP (catégorie de niveau de performances) selon l'UL 746A. Le numéro de CNP numérique (pas les performances) doit être inférieur ou égal à la valeur indiquée dans la colonne.

Les exigences de *ligne de fuite* pour les cartes de circuit imprimé exposées à des conditions environnementales de degré de pollution 3 doivent être déterminées en fonction du degré de pollution 3 du Tableau 10, dans "Autres isolants".

Si le chemin de la *ligne de fuite* est nervuré, la *ligne de fuite* du matériau isolant du groupe I peut alors être appliquée en utilisant un matériau isolant du groupe II, de même que peut être appliquée la *ligne de fuite* du matériau isolant du groupe II en utilisant un matériau isolant du groupe III. La *distance d'isolement* des nervures doit être égale ou supérieure à la dimension X dans le Tableau D.1. Pour le degré de pollution 2 et le degré de pollution 3, la hauteur des nervures doit être de 2 mm au moins.

Concernant les matériaux isolants inorganiques, par exemple le verre ou la céramique, qui ne cheminent pas, la *ligne de fuite* peut être égale à la *distance d'isolement* associée, telle que déterminée en 4.4.7.4.

4.4.7.5.3 Détermination

Les *lignes de fuite* pour l'*isolation fonctionnelle*, l'*isolation principale* et l'*isolation supplémentaire* doivent être dimensionnées selon le Tableau 10.

Tableau 10 – ***Lignes de fuite***

Colonne 1	2	3	4	5	6	7	8	9	10	11	12
Tension de fonctionnement **(valeur efficace)**	**Cartes de circuit imprimé** [a]		**Autres isolants**								
	Degré de pollution		**Degré de pollution**								
	1	**2**	**1**	**2**				**3**			
				Groupe de matériau isolant				**Groupe de matériau isolant**			
	[b]	[c]	[b]	**I**	**II**	**IIIa**	**IIIb**	**I**	**II**	**IIIa**	**IIIb**
V	mm	mm	mm	mm	mm	mm		mm	mm	mm	
≤ 2	0,025	0,04	0,056	0,35	0,35	0,35		0,87	0,87	0,87	
5	0,025	0,04	0,065	0,37	0,37	0,37		0,92	0,92	0,92	
10	0,025	0,04	0,08	0,40	0,40	0,40		1,0	1,0	1,0	
25	0,025	0,04	0,125	0,50	0,50	0,50		1,25	1,25	1,25	
32	0,025	0,04	0,14	0,53	0,53	0,53		1,3	1,3	1,3	
40	0,025	0,04	0,16	0,56	0,80	1,1		1,4	1,6	1,8	
50	0,025	0,04	0,18	0,60	0,85	1,20		1,5	1,7	1,9	
63	0,04	0,063	0,20	0,63	0,90	1,25		1,6	1,8	2,0	
80	0,063	0,10	0,22	0,67	0,95	1,3		1,7	1,9	2,1	
100	0,10	0,16	0,25	0,71	1,0	1,4		1,8	2,0	2,2	
125	0,16	0,25	0,28	0,75	1,05	1,5		1,9	2,1	2,4	
160	0,25	0,40	0,32	0,80	1,1	1,6		2,0	2,2	2,5	
200	0,40	0,63	0,42	1,0	1,4	2,0		2,5	2,8	3,2	
250	0,56	1,0	0,56	1,25	1,8	2,5		3,2	3,6	4,0	
320	0,75	1,6	0,75	1,6	2,2	3,2		4,0	4,5	5,0	
400	1,0	2,0	1,0	2,0	2,8	4,0		5,0	5,6	6,3	
500	1,3	2,5	1,3	2,5	3,6	5,0		6,3	7,1	8,0	
630	1,8	3,2	1,8	3,2	4,5	6,3		8,0	9,0	10,0	
800	2,4	4,0	2,4	4,0	5,6	8,0		10,0	11	12,5	[e]
1 000	3,2	5,0	3,2	5,0	7,1	10,0		12,5	14	16	
1 250	4,2	6,3	4,2	6,3	9	12,5		16	18	20	
1 600	[f]	[g]	5,6	8,0	11	16		20	22	25	
2 000			7,5	10,0	14	20		25	28	32	
2 500			10,0	12,5	18	25		32	36	40	
3 200			12,5	16	22	32		40	45	50	
4 000			16	20	28	40		50	56	63	
5 000			20	25	36	50		63	71	80	
6 300			25	32	45	63		80	90	100	
8 000			32	40	56	81		100	110	125	
10 000			40	50	71	100		125	140	160	
12 500			50	63	90	125		[d]	[d]	[d]	
16 000			63	80	110	150					
20 000			80	100	140	200					
25 000			100	125	180	250					
32 000			125	160	220	320					
L’interpolation est admise.											

Colonne 1	2	3	4	5	6	7	8	9	10	11	12
Tension de fonctionnement **(valeur efficace)**	**Cartes de circuit imprimé** [a]		**Autres isolants**								
	Degré de pollution		**Degré de pollution**								
	1	**2**	**1**	**2**				**3**			
				Groupe de matériau isolant				**Groupe de matériau isolant**			
	b	c	b	**I**	**II**	**IIIa**	**IIIb**	**I**	**II**	**IIIa**	**IIIb**
V	mm	mm	mm	mm	mm	mm		mm	mm	mm	

[a] Ces colonnes s'appliquent aussi à tous les *composants* ou parties des cartes de circuit imprimé et aux autres *lignes de fuite* ayant un contrôle de tolérance comparable.

[b] Tous groupes de matériaux.

[c] Tous groupes de matériaux sauf IIIb.

[d] Les valeurs des *lignes de fuite* ne sont pas déterminées pour cette plage.

[e] Les matériaux isolants du groupe IIIb ne sont généralement pas recommandés pour des degrés de pollution 3 supérieurs à 630 V.

[f] Au-delà de 1 250 V, utiliser les valeurs de la colonne 4.

[g] Au-delà de 1 250 V, utiliser les valeurs des colonnes 5 à 8, en utilisant le groupe de matériaux et la *tension de fonctionnement* appropriés.

Les *lignes de fuite* pour l'*isolation renforcée* doivent être égales à deux fois les distances exigées pour l'*isolation principale*.

Pour les fréquences fondamentales supérieures à 30 kHz, des exigences supplémentaires peuvent s'appliquer à l'Article F.3 et au Tableau F.3 pour la *tension de fonctionnement*.

Dans tous les cas, il n'est pas admis que la *ligne de fuite* associée soit inférieure à la *distance d'isolement* exigée.

La conformité des *lignes de fuite* doit être vérifiée selon 5.2.2.1 et selon l'Annex F si applicable.

4.4.7.6 Revêtement ou empotage

Un revêtement ou un empotage peut être utilisé pour isoler ou pour protéger une surface contre la pollution et pour permettre une réduction des *distances d'isolement* et des *lignes de fuite* (voir 4.4.7.8.4.3 et 4.4.7.8.5).

S'il est utilisé comme *isolation solide* pour une *protection principale,* une *protection en cas de défaut* et une *protection renforcée*, le revêtement ou l'empotage doit satisfaire aux exigences du 4.4.7.8.1 et du 4.4.7.10.

S'il est utilisé comme protection contre la pollution, les exigences de la protection de type 1 du 4.4.7.8.4.3 s'appliquent.

NOTE 1 En règle générale, le revêtement ou l'empotage est utilisé pour les *composants* et les sous-ensembles.

NOTE 2 Le revêtement pour l'amélioration du *système d'isolation* est bien connu dans le secteur industriel comme étant un revêtement conforme.

4.4.7.7 *Distance d'isolement* et *lignes de fuite* d'une carte de circuit imprimé et des *composants* assemblés sur une carte de circuit imprimé pour une *isolation fonctionnelle*

Les *distances d'isolement* et les *lignes de fuite* d'une carte de circuit imprimé et des *composants* assemblés sur une carte de circuit imprimé pour une *isolation fonctionnelle* doivent satisfaire aux exigences du 4.4.7.4 et du 4.4.7.5.

Il est admis de diminuer les *distances d'isolement* et les *lignes de fuite* sur la carte de circuit imprimé lorsque tous les éléments suivants sont satisfaits:

a) la carte de circuit imprimé a un taux d'inflammabilité minimal de V-0 (voir IEC 60695-11-10:2013);
b) le matériau de base de la carte de circuit imprimé possède un IRC (indice de résistance au cheminement) de 100;
c) la carte de circuit imprimé satisfait à l'essai de court-circuit pour les cartes de circuit imprimé (voir 5.2.4.11).

Il est admis de diminuer les *distances d'isolement* et les *lignes de fuite* des *composants* assemblés sur la carte de circuit imprimé

d) lorsqu'ils sont utilisés dans un environnement présentant un degré de pollution 1 ou un degré de pollution 2,
e) lorsqu'ils sont utilisés dans la catégorie de surtension I, et
f) lorsque la carte de circuit imprimé assemblée satisfait à l'essai de court-circuit pour les cartes de circuit imprimé (voir 5.2.4.11).

Dans ce cas, la spécification du fabricant de composants peut être utilisée.

4.4.7.8 *Isolation solide*

4.4.7.8.1 Généralités

Les matériaux choisis comme *isolation solide* doivent être conçus pour résister aux contraintes qui se produisent. Ces contraintes d'ordre mécanique, électrique, thermique, climatique et chimique sont celles qui peuvent survenir en fonctionnement normal. Les matériaux d'*isolation* doivent aussi résister au vieillissement pendant la *durée de vie prévue* du *BDM/CDM/PDS*.

Pour des fréquences fondamentales de la *tension de fonctionnement* supérieures à 30 kHz, l'Article F.4 doit être pris en compte.

NOTE L'*isolation solide* peut faire l'objet de contraintes par l'effet couronne, en particulier pour les champs hétérogènes. Pour assurer un fonctionnement sans effet couronne, il est soit possible d'utiliser des *distances d'isolement* supplémentaires soit d'améliorer la distribution de champ. Ce phénomène est proportionnel à l'augmentation de la contrainte de tension dans le système d'*isolation*.

Les essais doivent être effectués sur des *composants* et des sous-ensembles utilisant une *isolation solide* selon 4.4.7.10, afin d'assurer que la phase de conception ou de fabrication n'a pas altéré les performances de l'*isolation*.

Les *composants* doivent satisfaire à 4.13.

4.4.7.8.2 Exigences du matériau

Les matériaux qui, comme cela est spécifié ci-dessous, sont placés à une certaine distance des *parties actives* non isolées ou des contacts de commutation des circuits autres que des sources de puissance limitée selon 4.5.3 doivent être adaptées à la température maximale déterminée par l'essai d'échauffement du 5.2.3.10. Des considérations doivent être données pour savoir si oui ou non le matériau donne en plus de la résistance mécanique et si oui ou non la partie peut être sujette à des impacts pendant le fonctionnement.

Le matériau doit présenter n'importe quel taux d'inflammabilité et satisfaire aux valeurs HWI, HAI, et IRC applicables du Tableau 11 en fonction de son taux d'inflammabilité conformément à ce qui suit:

- Résistance du fil chaud à l'inflammation (HWI – *hot-wire resistance to ignition*)

  Les matériaux en contact direct ou respectant la distance selon le Tableau 12 avec les *parties actives* des circuits doivent respecter la valeur HWI (Hot Wire Ignition – Allumage avec fil chaud) selon le Tableau 11 ou l'essai au fil incandescent décrit en 5.2.5.3 à une température d'essai maximale de 850 °C, mais pas à moins de 550 °C, selon la classification de l'utilisation du *BDM/CDM/PDS* conformément à l'IEC 60695-2-11:2021, Figure A.1.

- Résistance à l'inflammation de l'arc à courant élevé (HAI – *high-current arc resistance to ignition*)

  Les matériaux se trouvant dans les limites de 12,7 mm des contacts de commutation des circuits et les matériaux se trouvant à une certaine distance selon le Tableau 12 des *parties actives* non isolées des circuits doivent respecter les valeurs HAI selon le Tableau 11.

- Indice de résistance au cheminement (IRC)

  Les matériaux respectant la distance selon le Tableau 12 par rapport aux *parties actives* non isolées des circuits qui présentent une *ligne de fuite* inférieure à 12,7 mm par rapport aux autres *parties actives* non isolées présentant des potentiels différents doivent respecter la valeur IRC selon le Tableau 11.

Les matériaux isolants thermoplastiques suivants utilisés doivent satisfaire à l'essai à la bille de l'IEC 60695-10-2:2014:

- matériaux en contact avec des *parties actives dangereuses* (support direct de la *partie active*);
- matériaux faisant partie intégrante de l'*enveloppe.*

La température assignée des parties en contact avec les *parties actives dangereuses* ne doit pas être inférieure à la *température ambiante* augmentée de l'échauffement maximal des parties à l'étude mesuré pendant l'essai du 5.2.3.10 et pas à moins de 95 °C.

Si le fabricant du matériau isolant fournit des données permettant de démontrer que les exigences ci-dessus sont satisfaites, aucun autre essai n'est exigé.

Tableau 11 – Exigences relatives au matériau *isolant*

	HWI		HAI		IRC		
Taux d'inflammabilité [a]	**Durée d'allumage [b]**	**CNP [c]**	**Arcs à l'allumage [d]**	**CNP [c]**	**IEC 60112 [e]**	**CNP [c,e]**	**CSA C22.2 N° 0.17 [f]**
HB	≥ 30 s	≤ 2	≥ 60	≤ 1	≥ 100	≤ 3	≥ 175
V-2	≥ 30 s	≤ 2	≥ 30	≤ 2	≥ 100	≤ 3	≥ 175
V-1	≥ 15 s	≤ 3	≥ 30	≤ 2	≥ 100	≤ 3	≥ 175
V-0 ou mieux	≥ 7 s	≤ 4	≥ 15	≤ 3	≥ 100	≤ 3	≥ 175

NOTE 1 Pour le Canada, la conformité doit être démontrée selon la CSA C22.2 N° 0.17.

NOTE 2 Les caractéristiques assignées de flamme selon l'IEC 60695-11-10:2013, l'IEC 60695-11-20:2015 et l'UL 94 sont considérées comme étant équivalentes, ces normes ayant été harmonisées. Les performances HWI et HAI selon les essais de 5.2.5.4 et de 5.2.5.2, et le HWI et l'IRC HAI selon l'UL 746A donnent un niveau comparable de sécurité selon la pratique. Les performances IRC selon l'IEC 60112 et l'IRC CNP selon l'UL 746A donnent un niveau comparable de sécurité selon la pratique.

NOTE 3 Certaines fiches techniques de matériau ou de *composant* peuvent spécifier un indice de tenue au cheminement (ITC) conforme à l'IEC 60112. Pour les besoins du présent document, l'ITC selon l'IEC 60112 est considéré comme étant équivalent à l'IRC de l'IEC 60112.

[a] Selon l'IEC 60695-11-10:2013, l'IEC 60695-11-20:1999/A1:2003, l'UL 94 ou la CSA C22.2 N° 0.17.

[b] Tel que déterminé par l'essai selon 5.2.5.4 ou les données du fabricant du matériau.

[c] CNP (catégorie de niveau de performances) selon l'UL 746A. Le numéro de CNP numérique (pas les performances) doit être inférieur ou égal à la valeur indiquée dans la colonne.

[d] Tel que déterminé par l'essai selon 5.2.5.2 ou les données du fabricant du matériau.

[e] Il peut également s'avérer nécessaire de prendre en considération 4.4.7.5.

[f] Un matériau dont la valeur IRC minimale est de 100 peut être utilisé si la tension concernée est inférieure ou égale à 250 V.

Tableau 12 – Distance par rapport aux *parties actives* non isolées pour la prise en considération du HWI, du HAI et de l'IRC

Degré de pollution	**Distance** mm
1	0,25
2	1,0
3	1,5

Aucune autre évaluation n'est exigée lorsque les matériaux génériques du Tableau 13 sont utilisés avec l'épaisseur minimale du Tableau 13, et la température mesurée lors de l'essai d'échauffement ne doit pas dépasser les limites de température du Tableau 13.

Tableau 13 – Matériaux génériques pour le matériau *isolant*

Matériau générique	Épaisseur minimale mm	Température maximale °C
Toute composition moulée à froid	Aucune limite	Aucune limite
Céramique, porcelaine	Aucune limite	Aucune limite
Diallyl phtalate	0,7	105
Époxy	0,7	105
Mélamine	0,7	130
Mélamine-phénolique	0,7	130
Phénolique	0,7	150
Nylon non rempli	0,7	105
Polycarbonate non rempli	0,7	105
Urée formaldéhyde	0,7	100

La conformité est vérifiée par

- l'*inspection visuelle* du 5.2.1,
- l'essai d'échauffement du 5.2.3.10,
- l'essai d'allumage d'un arc à forte intensité du 5.2.5.2, et
- l'essai au fil incandescent du 5.2.5.3 ou l'essai d'allumage avec fil chaud du 5.2.5.4.

4.4.7.8.3 Matériau pelliculé ou ruban

4.4.7.8.3.1 Généralités

Le paragraphe 4.4.7.8.3 concerne l'utilisation des matériaux pelliculés ou des rubans inférieurs à 0,7 mm dans des assemblages tels que les *composants* bobinés et les bus de raccordement.

Le paragraphe 4.4.7.8.3 ne concerne pas les *composants* faisant l'objet d'une norme de produits. Voir 4.13.

L'*isolation* constituée de matériaux pelliculés ou de ruban est admise, à condition qu'elle soit protégée contre les dommages mécaniques et qu'elle ne soit pas soumise à une contrainte mécanique en conditions normales d'utilisation.

Lorsque plusieurs couches d'*isolation* sont utilisées, aucune exigence ne stipule que toutes les couches soient composées du même matériau.

Une couche de ruban *isolant* se chevauchant à plus de 50 % est considérée comme constituant deux couches.

NOTE Une *isolation principale*, une *isolation supplémentaire* ou *double isolation* peut être appliquée en tant que *système* préassemblé de matériaux minces.

4.4.7.8.3.2 Épaisseur du matériau pelliculé ou ruban et nombre de couches

Le Tableau 14 spécifie le nombre de couches exigé en fonction de l'épaisseur du matériau pelliculé et du type d'*isolation*.

Tableau 14 – Épaisseur du matériau pelliculé ou ruban selon les exigences d'*isolation*

Type d'*isolation*	Épaisseur du matériau pelliculé ou ruban		Exigences
	< 0,2 mm	≥ 0,2 mm	
Isolation principale ***ou*** ***Isolation supplémentaire***	Au moins 1 couche	Au moins 1 couche	4.4.7.8.1, 4.4.7.10.2
Double isolation	--	Au moins 2 couches	Chaque couche: 4.4.7.8.1, 4.4.7.10.2 et toutes les couches ensemble 4.4.7.10.3
	Au moins 3 couches	--	Chaque couche: 4.4.7.8.1, 4.4.7.10.2 et 2 couches ensemble 4.4.7.10.3
Isolation renforcée	Au moins 3 couches de matériau non séparable qui ne peuvent pas être soumises à l'essai séparément	Au moins 1 couche, d'épaisseur minimale de 0,4 mm	4.4.7.8.1, 4.4.7.10.3

La conformité doit être vérifiée par les essais de 5.2.3.1 à 5.2.3.5.

Pour tous les *BDM/CDM/PDS haute tension*, un essai de décharge partielle (voir 5.2.3.5) est exigé dans tous les cas où plusieurs couches sont utilisées. Pour les parties basse tension d'un *BDM/CDM/PDS*, voir 4.4.7.10.3.

Lorsqu'un *composant* ou un sous-ensemble utilise des matériaux isolants pelliculés, il est permis de réaliser les essais sur le *composant* plutôt que sur le matériau.

L'essai de matériau est donné en 5.2.3.13.

4.4.7.8.4 Cartes de circuit imprimé

4.4.7.8.4.1 Généralités

Le matériau de carte de circuit imprimé doit présenter un taux d'inflammabilité de V-2 ou mieux et doit satisfaire au Groupe de matériau isolant IIIb ou mieux selon le Tableau 9.

NOTE Aux États-Unis, les cartes de circuit imprimé doivent être conformes à l'UL 796 (Standard for Printed-Wiring Boards) ou UL 796F selon le cas, et doivent être identifiées comme étant adaptées au support direct des *parties actives*.

Les exigences du 4.4.7.8.4 ne s'appliquent pas aux cartes de circuit imprimé ne contenant que des sources de puissance limitée selon 4.5.3.

Les cartes de circuit4.4.7.8.4 imprimé doivent satisfaire aux exigences appropriées du 4.4.7.10.1 et

- 4.4.7.10.2 pour l'*isolation principale*/l'*isolation supplémentaire*, ou
- 4.4.7.10.3 pour la *double isolation*/l'*isolation renforcée,* ou
- 4.4.7.7 pour l'*isolation fonctionnelle.*

4.4.7.8.4.2 Couches internes des cartes de circuit imprimé multicouches

L'*isolation* (fibres préimprégnées, prépreg) entre les couches conductrices des cartes de circuit imprimé multicouches et des cartes de circuit imprimé à âme métallique est une *isolation solide* selon l'IEC 60664-1:2020 et doit satisfaire aux exigences applicables du 4.4.7.8.1 et du 4.4.7.8.4.1.

NOTE 1 Pour plus d'informations, voir l'IEC 60664-3:2016, Article 1.

Les exigences du 4.4.7.8.3 pour le matériau pelliculé ou ruban ne sont pas applicables. Toutefois, une épaisseur minimale hors tout du matériau de 0,4 mm pour la *double isolation* et l'*isolation renforcée* s'applique à la carte de circuit imprimé finale.

L'*isolation* entre les pistes adjacentes d'une même couche conductrice interne doit être traitée comme

a) une *ligne de fuite* pour le degré de pollution 1 et une *distance d'isolement* selon le Tableau 8 et le Tableau 10 (voir la Figure D.14), ou
b) une *isolation solide*, auquel cas
   – elle doit satisfaire aux exigences applicables du 4.4.7.8.4.1,
   – elle doit satisfaire aux distances minimales du Tableau O.1 pour l'*isolation principale* et l'*isolation renforcée*,
   – Les exigences de *distance d'isolement* et de *lignes de fuite* selon le Tableau 8 et le Tableau 10 ne s'appliquent pas,
   – un échantillon de carte de circuit imprimé doit être préconditionné selon 5.2.3.16 suivi d'un *essai de type* selon 5.2.3 comme cela est spécifié en 4.4.7.8.4.1, et
   – aucun *essai individuel de série* n'est exigé sur la carte de circuit imprimé finale.

NOTE 2 Pour les matériaux FR4, la résistance à la tension par épaisseur peut être estimée à 30 kV/mm.

Une couche interne de carte de circuit imprimé est représentée à la **Figure D.14**.

4.4.7.8.4.3 Utilisation d'un matériau de revêtement

Un matériau de revêtement utilisé pour assurer une *isolation fonctionnelle*, une *isolation principale*, une *isolation supplémentaire* ou une *isolation renforcée* doit satisfaire aux exigences spécifiées ci-dessous.

Une protection de type 1 (comme définie dans l'IEC 60664-3) améliore le microenvironnement des parties protégées. La *distance d'isolement* et la *ligne de fuite* du Tableau 8 et du Tableau 10 pour un degré de pollution 1 s'appliquent sous cette protection. Entre les deux parties conductrices, il est exigé qu'au moins l'une des deux parties conductrices, ainsi que l'ensemble des *distances d'isolement* et des *lignes de fuite* entre ces parties, soient couvertes par la protection.

La protection de type 2 est considérée comme similaire à une *isolation solide*. Sous la protection, les exigences en matière d'*isolation solide* spécifiées en 4.4.7.8 sont applicables, y compris le matériau de revêtement lui-même, et les *distances d'isolement* et les *lignes de fuite* ne doivent pas être inférieures à celles indiquées dans l'IEC 60664-3:2016, Tableau 1, qui est reproduit dans le Tableau O.1. Les exigences de *distance d'isolement* et de ligne de fuite dans le Tableau 8 et le Tableau 10 ne s'appliquent pas. Entre deux parties conductrices, il est exigé que ces deux parties, ainsi que les *distances d'isolement* et les *lignes de fuite* entre elles, soient couvertes par la protection de sorte qu'il n'existe aucun espace libre entre le matériau de protection, les parties conductrices et les cartes imprimées.

Le matériau de revêtement utilisé pour fournir une protection de type 1 et de type 2 doit être conçu pour résister aux contraintes susceptibles de survenir pendant la *durée de vie prévue* du *BDM/CDM/PDS*.

Un *essai de type* sur une carte de circuit imprimé représentative doit être effectué selon l'IEC 60664-3:2016, Article 5. Le nombre d'échantillons est défini dans l'IEC 60664-3:2016. Un préconditionnement selon 5.2.3.16 est exigé avant de procéder à l'*essai de type*.

Aucun *essai individuel de série* n'est exigé.

4.4.7.8.5 Matériaux d'empotage

Un matériau d'empotage peut être utilisé comme *isolation solide* ou comme revêtement de protection contre la pollution S'il est utilisé comme *isolation solide* pour une *protection principale*, une *protection en cas de défaut* et une *protection renforcée*, il doit satisfaire aux exigences du 4.4.7.8.4.2 b), à l'exception du terme "carte de circuit imprimé" qui est remplacé par "échantillon enrobé".

L'*inspection visuelle* du 5.2.1 doit être réalisée selon l'essai spécifié en 4.4.7.8.4.2 b) afin de démontrer que les échantillons d'essai ne présentent aucun

- cloquage,
- gonflement,
- séparation par rapport au matériau de base,
- fissure,
- vide, et
- zone avec parties conductrices adjacentes non protégées, à l'exception du terrain.

S'il est utilisé comme protection contre la pollution, les exigences de la protection de type 1 du 4.4.7.8.4.3 s'appliquent.

4.4.7.9 Raccordement des parties de l'*isolation solide* (joints scellés)

Les chemins de la *distance d'isolement* et de la *ligne de fuite* en présence d'un joint scellé entre deux parties isolantes sont déterminés comme suit. Un exemple est donné à la Figure D.9.

- Une protection de type 1 ou de type 2 telle que décrite en 4.4.7.8.4.3 s'applique.
- Un joint scellé qui n'est pas évalué comme assurant une protection de type 1 ou de type 2 n'est pas considéré comme une *isolation solide* ni réputé réduire le degré de pollution. Les *distances d'isolement* et les *lignes de fuite* du 4.4.7.4 et du 4.4.7.5 s'appliquent pour le degré de pollution de l'environnement autour de l'assemblage.

Voir 5.2.5.6 pour le préconditionnement et l'essai.

4.4.7.10 Exigences sur la capacité en tenue électrique

4.4.7.10.1 Généralités

S'il s'avère impossible de vérifier l'*isolation* par l'*inspection visuelle* du 5.2.1 selon 5.2.2.1, l'essai selon 4.4.7.10.2 ou 4.4.7.10.3 s'applique entre les circuits à l'étude et, pour l'*isolation solide*, sur les *composants* et les sous-ensembles.

4.4.7.10.2 *Isolation principale* ou *isolation supplémentaire*

L'*isolation principale* ou l'*isolation supplémentaire* doit être soumise à l'essai comme suit:

- *tension de tenue aux chocs selon* 5.2.3.2 ou tension alternative ou tension continue selon 5.2.3.3; et
- tension alternative ou tension continue selon 5.2.3.4.

4.4.7.10.3 *Double insolation* ou *isolation renforcée*

La *double isolation* ou l'*isolation renforcée* doit être soumise à l'essai comme suit:

- *tension de tenue aux chocs selon* 5.2.3.2 ou tension alternative ou tension continue selon 5.2.3.3; et
- tension alternative ou tension continue selon 5.2.3.4;

Pour l'*isolation solide*, l'essai de décharge partielle selon 5.2.3.5 doit être réalisé en plus des essais ci-dessus, si

- la *tension de fonctionnement* de crête répétitive appliquée à l'*isolation* est supérieure à 750 V, et
- la contrainte de tension sur l'*isolation* est supérieure à 1 kV/mm.

La contrainte de tension est la *tension de fonctionnement* (crête répétitive) divisée par la distance entre les deux parties de potentiels différents. Voir la Figure D.14.

L'essai de décharge partielle doit être effectué comme un *essai de type* sur tous les *composants*, sous-ensembles et cartes de circuit imprimé. De plus, un *essai sur prélèvement* doit être effectué si l'isolation est constituée d'une couche unique de matériau, comme les constructions pouvant être endommagées par une décharge partielle dans le vide en cas d'exposition à la contrainte de tension décrite ci-dessus (résine coulée, empotage, moulage, fil à triple isolation, etc.).

La *double isolation* doit être conçue de façon telle qu'une défaillance de l'*isolation principale* ou de l'*isolation supplémentaire* n'ait pas pour conséquence une réduction des capacités d'*isolation* de la partie restante de l'*isolation*.

4.4.8 Compatibilité avec les dispositifs de protection à courant différentiel résiduel (DDR)

Outre la *protection principale* et la *protection en cas de défaut* assurées par le *BDM/CDM/PDS,* certaines *installations* domestiques et industrielles fournissent un DDR comme protection supplémentaire contre les défauts d'*isolation*.

NOTE 1 Un disjoncteur intégrant une fonction de courant différentiel résiduel (CBR – *residual current function*) selon l'IEC 60947-2:2016 et l'IEC 60947-2:2016/AMD1:2019, Annexe B, et un dispositif modulaire à courant différentiel résiduel (MRCD – *modular residual current device*) selon l'IEC 60947-2:2016 et l'IEC 60947-2:2016/AMD1:2019, Annexe M, sont équivalents à un DDR.

NOTE 2 Cette exigence ne concerne pas les États-Unis et le Canada.

Un *défaut d'isolation* ou un contact direct avec certains types de circuits du *BDM/CDM/PDS* peut provoquer un courant de défaillance à composante continue dans le *conducteur mise à la terre de protection* qui, par conséquent, réduit la capacité d'un DDR de type A ou de type AC (voir l'IEC 60755) à fournir cette protection pour un autre équipement de l'*installation*.

Pour assurer le fonctionnement prévu du DDR fourni par l'*installation*, le *BDM/CDM/PDS* doit satisfaire à l'une des conditions suivantes a) ou b).

a) Les *BDM/CDM/PDS* monophasés qui sont des *équipements enfichables de type A* doivent être conçus de sorte que, dans les conditions normales de fonctionnement et les *conditions de premier défaut*, un courant obtenu à composante continue superposée lisse du courant dans le *conducteur de mise à la terre de protection* ne dépasse pas les exigences de tenue aux courants continus de 6 mA de l'IEC 60755 pour le DDR de type A ou de 10 mA pour le type F.
b) Pour les *BDM/CDM/PDS* qui sont des *équipements enfichables de type B* ou qui sont destinés à être *connectés en permanence*, le courant continu dans le *conducteur de mise à la terre de protection* n'est pas limité si les informations et les exigences de marquage du 6.3.9.5 sont satisfaites.

Si les courants du *conducteur de mise à la terre de protection* à composante continue superposée lisse dépassent les valeurs ci-dessus, des dispositifs de protection adaptés doivent être choisis et indiqués dans la documentation destinée au client (DDR de type B ou de type F, par exemple).

Le fabricant du *BDM/CDM/PDS* doit donner des informations pour assurer la compatibilité avec le DDR fourni par l'*installation.* Elle doit être vérifiée par simulation ou calcul du courant dans le *conducteur de mise à la terre de protection* dans les conditions de fonctionnement normal et les *conditions de premier défaut* conformément aux lignes directrices de l'Annex H.

Voir 6.3.9.5 pour les exigences relatives aux informations et au marquage.

4.4.9 Décharge de condensateurs

Pour la protection contre les dangers de chocs électriques, les condensateurs à l'intérieur du *BDM/CDM/PDS* doivent être déchargés à une tension inférieure à U_{DCL} de la *CTD As* ou à une énergie résiduelle inférieure à 0,5 mJ, après avoir éliminé l'énergie du *PDS*.

a) Pour les *BDM/CDM/PDS* d'*équipement enfichable de type A* et d'*équipement enfichable de type B*, le temps de décharge ne doit pas dépasser 1 s ou les *parties actives dangereuses* doivent être protégées contre le contact direct au moins au niveau IP2X (voir 4.4.3.3).
b) Pour les *BDM/CDM/PDS connectés en permanence*, le temps de décharge ne doit pas dépasser 5 s.
c) Pour les *BDM/CDM/PDS* enfichables et *connectés en permanence* avec un système de commande qui empêche d'accéder aux condensateurs, jusqu'à leur décharge comme cela est indiqué ci-dessus, aucun temps de décharge n'est exigé.

Pour les *BDM/CDM/PDS* qui ne satisfont pas aux exigences ci-dessus a), b) ou c), l'accès doit uniquement être possible à l'aide d'un outil ou d'une clé, et les informations et exigences relatives aux informations et au marquage du 6.5.2 s'appliquent.

Cette exigence s'applique également aux condensateurs utilisés pour la correction du facteur de puissance, le filtrage, etc.

NOTE L'exigence du 4.4.9 prend en considération uniquement l'énergie emmagasinée liée aux condensateurs internes du *BDM/CDM*. Pour l'application finale dans laquelle le *BDM/CDM* est utilisé comme un *composant*, et dans laquelle d'autres sources d'énergie peuvent être présentes, des considérations supplémentaires en matière de charge emmagasinée peuvent s'appliquer. Voir également 4.8 pour les sources d'alimentation multiples.

La conformité est vérifiée par l'essai du 5.2.3.8.

Voir 6.5.2 pour les exigences relatives aux informations et au marquage.

4.4.10 Conditions d'accès pour les parties *haute tension* du *BDM/CDM/PDS* (*verrouillage*)

4.4.10.1 Généralités

Les parties sous haute tension (transformateur, convertisseur, moteur, etc.) doivent être protégées pour la sécurité des personnes.

- L'accès des personnes aux parties haute tension d'un *BDM/CDM/PDS* doit être empêché. Cette protection est assurée par une enveloppe appropriée conforme à l'IEC 60204-11:2018 pour la sécurité des personnes ou est soumise aux règles de l'*installation* (exemple IEC 61936-1).

- Si une *enveloppe* est utilisée, des *verrouillages* doivent être utilisés pour empêcher l'accès à l'intérieur de l'*enveloppe* de la partie haute tension lorsque des disjoncteurs de *réseau* fournissant la haute tension au circuit sont activés (voir b) ci-dessous). Des *verrouillages* sont exigés sur toutes les *portes*. Les *verrouillages* ne sont pas exigés sur les *panneaux articulés* ou les *capots*.

NOTE 1 Les exigences sont issues de l'UL 347A.

NOTE 2 Un *panneau articulé* peut être composé de trois côtés boulonnés et d'une charnière boulonnée, soudée ou sécurisée d'une manière similaire.

a) Conditions de fonctionnement

   Le verrouillage des *portes* doit empêcher tout accès à l'intérieur de l'*enveloppe* de la section haute tension du convertisseur lorsque le ou les disjoncteurs *de réseau* fournissant la haute tension au circuit sont activés et que les *parties actives dangereuses* n'ont pas été reliées à la terre – voir b).

b) Accès pour la maintenance – Instructions de mise à la terre

   La mise à la terre s'effectue après le temps normal de décharge indiqué par le fabricant du *BDM/CDM/PDS*. Il faut assurer que cette action est sans danger même en cas de défaillance du circuit de décharge. Il faut également prendre soin que sur le côté entrée ou le côté sortie du *BDM/CDM/PDS*, les capacités réparties des câbles, du moteur et/ou du transformateur doivent aussi être déchargées avant que tout accès aux *parties actives* ne soit possible. Les exigences du 4.4.9 s'appliquent.

   Des dispositifs de mise à la terre (sectionneurs de terre et/ou câbles de mise à la terre) doivent être fournis en quantité suffisante pour faciliter un travail en toute sécurité sur les *parties actives* de l'équipement haute tension du *PDS*. Les dispositifs de mise à la terre doivent être conformes aux exigences appropriées de l'IEC 62271-102:2018 ou de l'IEC 61230:2008. Les contacts de mise à la terre ou un moyen permettant d'indiquer que les contacts des sectionneurs sont fermés doivent être visibles par le personnel de maintenance avant qu'il n'accède à l'équipement.

   NOTE 3 Dans certains cas particuliers (par exemple convertisseurs à charge commutée), deux dispositifs de mise à la terre (un côté réseau, un côté alimentation) peuvent être exigés.

Pour les parties qui ne sont pas directement mises à la terre par un sectionneur de terre, les fabricants de *composants* doivent fournir les instructions de sécurité pour effectuer la mise à la terre.

Pour l'essai, voir 5.2.2.8

Pour le marquage, voir 6.3.9.6 et 6.5.7.

4.4.10.2 Moyens d'*isolation* des *BDM/CDM/PDS haute tension*

4.4.10.2.1 *BDM/CDM/PDS* avec dispositifs d'isolation

4.4.10.2.1.1 Généralités

Les dispositifs d'isolation doivent être des dispositifs d'isolation de circuit d'alimentation actionnables de l'extérieur et à commande simultanée avec une indication de position conforme aux paragraphes de 4.4.10.2.1.1 à 4.4.10.2.1.5.

Pour l'essai, voir 5.2.2.8.

Des exemples de dispositifs d'isolation possibles sont donnés ci-après:

a) commutateur d'isolation tripolaire;
b) commutateur d'isolation tripolaire combiné mécaniquement à des fusibles de circuit de moteur haute tension;
c) commutateur de coupure de charge tripolaire;
d) contacteur tripolaire détaché (avec ou sans fusible);
e) disjoncteur tripolaire détaché.

4.4.10.2.1.2 Emplacement de fonctionnement

Le mécanisme d'isolation indiqué en 4.4.10.2.1.1 doit être placé dans un endroit n'exposant pas l'opérateur aux parties sous tension, et doit être disposé afin de permettre l'ouverture de tous les conducteurs non mis à la terre du circuit simultanément en une seule manœuvre. Lorsqu'un dispositif de déconnexion déconnecte un *conducteur de mise à la terre de protection* permanent, il doit ouvrir simultanément tous les conducteurs sous tension et le *conducteur de mise à la terre de protection*.

4.4.10.2.1.3 Visibilité de l'ouverture isolante

Les moyens d'isolation doivent fournir une indication visuelle d'une ouverture isolante dans le circuit.

L'ouverture d'isolation ou un indicateur mécanique doit être visible à travers une fenêtre. L'opérateur mécanique doit être actionné par le mouvement de l'appareillage de commande d'isolation actuel, par l'obturateur d'un assemblage détaché, etc. L'action de l'indicateur mécanique ne doit pas dépendre du mouvement de la manette de commande ou du mécanisme de commande seul.

4.4.10.2.1.4 Verrouillage

Les dispositifs d'isolation haute tension doivent être verrouillés comme cela est indiqué en 4.4.10.1.

Les dispositifs d'isolation haute tension doivent comporter des moyens de verrouillage mécaniques en position ouverte.

4.4.10.2.1.5 Mise hors tension des couteaux de contact

Tous les couteaux de contact côté charge doivent être mis hors tension lorsque le contact est en position ouverte, à l'exception des contacts destinés à être mis sous tension des deux côtés (barre omnibus, sectionnement de boucle, par exemple). Ces contacts ne doivent être mis sous tension qu'en position ouverte, sauf si

a) les barrières et *enveloppes* sont installées sur les contacts pour éviter de toucher ces derniers lorsque leurs couteaux sont sous tension, et
b) le contact est marqué selon 6.5.7.

4.4.10.2.2 *BDM/CDM/PDS* sans dispositif d'isolation

Les *BDM/CDM/PDS* sans les dispositifs d'isolation indiqués en 4.4.10.2.1 doivent satisfaire à a) et b) ci-dessous:

a) le *BDM/CDM/PDS* doit être marqué selon 6.5.7;
b) des instructions doivent être fournies en ce qui concerne les dispositifs d'isolation externes et le verrouillage selon 6.5.7.

4.5 Protection contre les dangers dus à l'énergie électrique

4.5.1 Généralités

Le paragraphe 4.5 donne des exigences relatives à la protection contre les dangers dus à l'énergie électrique. Ces dangers ne sont pas liés aux chocs électriques du 4.4, aux dangers d'incendie du 4.6 ou aux brûlures du 4.6.5.

Il s'agit, par exemple, de la chaleur, de l'explosion sous pression, de l'expulsion de produits chimiques, etc.

La défaillance de n'importe quel *composant* à l'intérieur du *BDM/CDM/PDS* ne doit pas libérer l'énergie suffisante pour entraîner des dangers.

S'il y a lieu, l'éventualité d'un transfert d'énergie du moteur vers les *BDM/CDM* doit être prise en considération lorsque le matériel entraîné surcharge le contrôle des *BDM/CDMP*.

Un risque de blessure due à un danger dû à l'énergie électrique existe en présence d'énergie électrique dangereuse entre au moins deux *parties actives* non isolées (dont l'une peut être reliée à la terre) qui peuvent être pontées, lorsqu'elles sont soumises à l'essai avec le doigt d'essai joint conformément à la Figure M.2, en position articulée.

Les *BDM/CDM/PDS* doivent être conçus de manière à ne présenter aucun risque de danger dû à l'énergie électrique provenant de circuits accessibles en

- limitant l'énergie selon 4.5.3, ou
- en prévoyant des *enveloppes*, des barrières, des protecteurs et des dispositifs similaires selon 4.4.3.3.1, qui peuvent uniquement être retirés à l'aide d'un outil ou d'une clé.

La conformité est vérifiée par l'essai de non-accessibilité du 5.2.2.2.

4.5.2 Détermination du niveau d'énergie électrique dangereux

4.5.2.1 Généralités

Il est considéré qu'un niveau d'énergie électrique dangereux existe si la tension est d'au moins 2 V ou si au moins l'une des situations suivantes s'applique:

a) la puissance disponible dépasse la limite des sources de puissance limitée du 4.5.3;
b) l'énergie emmagasinée dépasse 20 J.

La conformité de la puissance disponible doit être vérifiée par 5.2.3.9 et l'énergie emmagasinée doit être vérifiée par calcul, comme suit:

$$E \leq 0{,}5 \times CU^2$$

où

E est l'énergie stockée, en joules (J);

C est la capacité, en farads (F);

U est la tension mesurée sur le condensateur, en volts (V).

4.5.2.2 Énergie électrique emmagasinée

Les condensateurs à l'intérieur d'un *BDM/CDM/PDS* doivent être déchargés à un niveau d'énergie inférieur à celui indiqué en 4.5.2.1 b), dans les 5 s qui suivent le retrait de la tension d'alimentation du *PDS*. Si cette exigence ne peut être satisfaite pour des raisons fonctionnelles ou d'autres raisons, les informations et les exigences de marquage du 6.5.2 s'appliquent.

La conformité est vérifiée par l'inspection visuelle du 5.2.1 du BDM/CDM/PDS et des schémas de circuit correspondants, en tenant compte de la possibilité de déconnexion avec un commutateur "MARCHE"/"ARRÊT" dans n'importe quelle position et du non-fonctionnement des dispositifs de consommation de puissance périodique ou des composants à l'intérieur du PDS. Si le temps de décharge du condensateur ne peut pas être calculé avec exactitude, il doit être mesuré selon 5.2.3.8.

4.5.3 Sources de puissance limitée

Les sources de puissance limitée peuvent être utilisées pour réduire le plus possible le risque de feu et le risque dû à l'énergie. Une source de puissance limitée doit satisfaire à l'une des exigences suivantes:

a) la sortie est par nature limitée conformément au Tableau 15;
b) une impédance linéaire ou non linéaire limite la sortie conformément au Tableau 15. Si un dispositif à coefficient de température positif (PTC, par exemple) est utilisé, il doit réussir tous les essais applicables spécifiés dans l'IEC 60730-1:2013, l'IEC 60730-1:2013/AMD1:2015 et l'IEC 60730-1:2013/AMD2:2020;
c) un réseau de régulation limite la sortie conformément au Tableau 15 avec et sans *condition de premier défaut* dans le réseau de régulation;
d) un dispositif de protection contre les *surintensités* est utilisé, et la sortie est limitée conformément au Tableau 16.

Si la source de puissance limitée dépend du ou des dispositifs de protection contre les *surintensités*, le courant nominal de l'un au moins des dispositifs de protection dans la circulation du courant ne doit pas dépasser la limite indiquée dans le Tableau 16, et il doit s'agir d'un fusible ou d'un dispositif électromécanique non réglable et non réinitialisable.

Une source de puissance limitée utilisée à partir d'un *réseau* en courant alternatif ou une source de puissance limitée fonctionnant avec une batterie et rechargée sur le *réseau* en courant alternatif lorsqu'elle assure l'alimentation doit intégrer un transformateur de séparation.

La conformité de la détermination de la puissance disponible maximale est vérifiée par l'essai du 5.2.3.9.

Tableau 15 – Limites pour les sources d'alimentation sans dispositif de protection contre les *surintensités*

Tension de sortie[a] U_{oc}		Courant de sortie [b d] I_{sc}	Puissance apparente [c d] S
V courant alternatif (valeur efficace)	V courant continu	A	VA
≤ 30	≤ 30	≤ 8	≤ 100
-	30 < U_{oc} ≤ 60	≤ 150 / U_{oc}	≤ 100

[a] U_{oc}: Tension de sortie mesurée selon 5.1.5.3 avec tous les circuits déconnectés. Les tensions concernent le courant alternatif sensiblement sinusoïdal et le courant continu sans ondulation. Pour le courant alternatif non sinusoïdal et le courant continu présentant une ondulation supérieure à 10 % de la crête, la tension de crête ne doit pas dépasser 42,4 V.

[b] I_{sc}: Courant de sortie maximal avec charge non capacitive, y compris un court-circuit.

[c] S (VA): Puissance apparente de sortie maximale en VA avec un charge non capacitive.

[d] I_{sc} et S sont mesurés 5 s après l'application de la charge si la protection est assurée par un circuit électronique ou un dispositif à coefficient de température positif (PTC, par exemple), et 60 s après dans d'autres cas.

Tableau 16 – Limites pour les sources d'alimentation avec dispositif de protection contre les *surintensités*

Tension de sortie[a] U_{oc}		**Courant de sortie** [b d] I_{sc} A	**Puissance apparente** [c d] S VA	**Courant nominal du dispositif de protection contre les *surintensités*** [e] A
V courant alternatif (valeur efficace)	V courant continu			
≤ 20	≤ 20	≤ 1 000/U_{oc}	≤ 250	≤ 5,0
20 < U_{oc} ≤ 30	20 < U_{oc} ≤ 30			≤ 100/U_{oc}
–	30 < U_{oc} ≤ 60			≤ 100/U_{oc}

[a] U_{oc}: Tension de sortie mesurée selon 5.1.5.3 avec tous les circuits déconnectés. Les tensions concernent le courant alternatif sensiblement sinusoïdal et le courant continu sans ondulation. Pour le courant alternatif non sinusoïdal et le courant continu présentant une ondulation supérieure à 10 % de la crête, la tension de crête ne doit pas dépasser 42,4 V.

[b] I_{sc}: Courant de sortie maximal avec charge non capacitive, y compris un court-circuit, mesuré 60 s après l'application de la charge.

[c] S (VA): VA de sortie maximal avec charge non capacitive mesuré 60 s après l'application de la charge.

[d] Les impédances de limitation de courant restent dans le circuit pendant le mesurage, mais les dispositifs de protection contre les *surintensités* sont contournés. La raison justifiant de procéder aux mesurages en contournant les dispositifs de protection contre les *surintensités* est qu'il s'agit de déterminer la quantité d'énergie disponible pour provoquer une éventuelle surchauffe pendant le temps de fonctionnement des dispositifs de protection contre les *surintensités*.

[e] Courants nominaux des dispositifs de protections contre les *surintensités* qui coupent le circuit dans les 120 s avec un courant égal à 210 % du courant nominal spécifié dans le tableau.

L'essai du 5.2.3.9 peut être ignoré si les dispositifs de protection contre les *surintensités* sont utilisés conformément à

- l'IEC 60127-2:2014, Feuille 3, 4, 6 ou 8 ou
- l'IEC 60127-4.

NOTE Aux États-Unis et au Canada, les dispositifs de protection contre les surintensités utilisés doivent être conformes:

- à l'UL 248-14/CSA C22.2 No.248.14, ou
- aux microfusibles UL 248-14/CSA C22.2 No.248.14

Les fusibles satisfaisant aux normes de *composants* indiquées ci-dessus limitent le courant maximal et la puissance apparente maximale à des valeurs inférieures aux limites du Tableau 16 en moins de 60 s, selon les durées maximales d'ouverture et de préarc spécifiées dans les normes de *composants* applicables.

4.6 Protection contre les dangers d'incendie et thermiques

4.6.1 Généralités

La protection contre les dangers d'incendie et thermiques dans des conditions normales de fonctionnement, dans des *conditions anormales de fonctionnement* et dans des *conditions de premier défaut*, est essentielle à la sécurité du *BDM/CDM/PDS* et incluent les éléments suivants:

- Analyse de circuit des *conditions anormales de fonctionnement* et des *conditions de premier défaut* selon 4.2, en prenant en considération
  - les essais de court-circuit en sortie selon 5.2.4.5,
  - les essais de surcharge du moteur électronique selon 5.2.4.6,
  - l'essai de surcharge en sortie selon 5.2.4.9,
  - les essais de défaillance de *composants* selon 5.2.4.10,
  - la *coordination de l'isolation* pour l'*isolation fonctionnelle* sur les cartes de circuit imprimé et les *composants* selon 4.4.7.3, 4.4.7.4, 4.4.7.5 et 4.4.7.7, et
  - l'utilisation de matériaux polymères ignifuges pour l'*enveloppe* et la partie *composants* de l'*enveloppe* selon 4.6.4.2;
- conditions de fonctionnement normal en prenant en considération les limites de températures des *composants* et du matériau selon 4.6.5.

NOTE En règle générale, une *enveloppe ignifuge* est considérée comme n'étant pas applicable pour la construction de *BDM/CDM/PDS* industriels dans une autre application lorsqu'ils sont couverts par une norme (l'IEC 60204-1 et l'IEC 61439-1, par exemple).

Si ces mesures s'avèrent insuffisantes pour atténuer le feu de manière suffisante, les exigences relatives aux matériaux ignifuges, aux *composants* et aux températures du matériau, ainsi que d'autres mesures d'atténuation, sont couvertes de 4.6.2 à 4.6.4.4.

4.6.2 Circuits et *composants* représentant un danger d'incendie

Les types de circuits et de *composants* suivants doivent être considérés comme présentant un potentiel danger d'incendie:

- les circuits directement connectés au *réseau*;
- les circuits qui sont directement connectés à l'*alimentation non raccordée directement au réseau*, mais qui dépassent les limites des sources de puissance limitée du 4.5.3;
- les *composants* comportant des parties d'arc qui ne sont pas sous enveloppe.

Une atténuation appropriée du risque selon 4.6.3 et 4.6.4 peut être applicable pour le *BDM/CDM/PDS*.

Pour les *composants* d'un circuit ne présentant aucun danger d'incendie, 4.6.2 ne s'applique pas.

4.6.3 Sélection des *composants* pour atténuer le risque d'un danger d'incendie

Le risque d'inflammation dû à une température élevée doit être réduit le plus possible par la sélection appropriée et la bonne utilisation des *composants* et par une fabrication adéquate.

Les *composants* électriques doivent être utilisés de manière à ce que leur température maximale de fonctionnement dans des conditions normales de fonctionnement, dans des *conditions anormales de fonctionnement* et dans des *conditions de premier défaut* soit inférieure à celle nécessaire à l'inflammation des *composants* et des matériaux environnants.

Dans des conditions normales de fonctionnement, les limites du Tableau 17 ne doivent pas être dépassées pour les *composants* ou leurs matériaux environnants.

Lorsqu'il n'est pas pratique de protéger les *composants* contre la surchauffe dans les *conditions anormales de fonctionnement* et les *conditions de premier défaut*, tous les matériaux en contact avec de tels *composants* doivent être de classe d'inflammabilité V-1, ou mieux selon l'IEC 60695-11-10:2013.

La conformité doit être confirmée par l'*inspection visuelle* du 5.2.1 des *composants* et des fiches techniques des matériaux et, si nécessaire, par des essais.

4.6.4 Protection contre le feu fournie par les *enveloppes*

4.6.4.1 Généralités

Le danger d'incendie doit être atténué en satisfaisant aux exigences du 4.6.4.2 et à l'une des mesures suivantes a) ou b):

a) le *BDM/CDM/PDS* de *type ouvert* est destiné à être placé dans une *enveloppe* supplémentaire ou dans une *zone d'accès limité* assurant la protection de l'atténuation du feu selon 4.6.4.3;

b) le *BDM/CDM* est conçu avec une *enveloppe* qui atténue le feu selon 4.6.4.4.

4.6.4.2 Exigences générales relatives à l'*enveloppe*

Les matériaux utilisés pour les *enveloppes* doivent satisfaire aux exigences du 5.2.5.5.

Les métaux, les matières céramiques et le verre trempé résistant à la chaleur, armé ou feuilleté, sont considérés comme satisfaisants sans qu'un essai soit nécessaire.

Les matériaux non métalliques, non céramiques et qui ne sont pas en verre sont considérés comme satisfaisant à l'essai si, dans l'épaisseur minimale utilisée, le matériau appartient à la classe d'inflammabilité 5VA, conformément à l'IEC 60695-11-20:2015.

Les *composants* bouchant une ouverture dans une *enveloppe* et qui sont destinés à être installés à cet effet n'ont pas besoin d'être évalués quant aux exigences d'inflammabilité du 5.2.5.5, à condition qu'ils satisfassent aux aspects d'inflammabilité de la norme de *composant* applicable. Voir également 4.13.

EXEMPLE Porte-fusibles, des interrupteurs, des voyants lumineux, des connecteurs et des socles de connecteur.

La conformité se vérifie par l'*inspection visuelle* du 5.2.1 et, si nécessaire, par des essais.

Le fabricant du *BDM/CDM/PDS* peut utiliser des informations en provenance du fournisseur de *composants* ou du matériau isolant de l'*enveloppe* pour prouver la conformité aux exigences ci-dessus. Dans ce cas, il n'est pas exigé d'essai supplémentaire.

4.6.4.3 *BDM/CDM* de *type ouvert* destiné à être installé dans une *enveloppe* supplémentaire ou dans une *zone d'accès limité*

Un *BDM/CDM* de *type ouvert* n'a pas besoin d'assurer la protection contre la propagation du feu.

Pour le marquage, voir 6.3.6.1.

NOTE Si la protection contre l'atténuation du danger d'incendie est assurée par une *enveloppe* supplémentaire dans l'application finale, l'atténuation du feu doit par hypothèse être couverte par la norme couvrant cette application (IEC 61439-1, IEC 60204-1, par exemple).

4.6.4.4 *BDM/CDM* conçu pour atténuer le danger d'incendie au moyen de l'*enveloppe*

Les éléments suivants s'appliquent:

- le BDM/CDM est construit dans une *enveloppe ignifuge* satisfaisant aux exigences générales en matière d'*enveloppe* du 4.6.4.2;
- le BDM/CDM est construit dans une *enveloppe ignifuge* satisfaisant aux exigences en matière d'*enveloppe ignifuge* de l'IEC 62477-1:2022; 4.6.3;
- les ouvertures doivent être inférieures à 2,5 mm en petite dimension, sauf si une analyse du risque réalisée selon 4.2 peut démontrer que la construction fournit une protection adaptée pour l'atténuation du danger d'incendie.

4.6.5 Limites de température

4.6.5.1 Généralités

Les parties internes et les parties de l'enveloppe externe du *BDM/CDM/PDS* ne doivent pas atteindre des températures pouvant mener à un risque de feu, de brûlure ou de choc électrique dû à des températures élevées dans les conditions normales de fonctionnement et avec les caractéristiques assignées comme cela est défini en 5.2.3.10.

Les autres conditions de fonctionnement assignées telles que le fonctionnement en cycle de service, l'allègement thermique, le fonctionnement en altitude au-dessus de 1 000 m, les conditions de surintensité temporaire et les caractéristiques de commande de refroidissement doivent être soumises à l'essai ou calculées.

La conformité est vérifiée par l'essai du 5.2.3.10.

Pour le marquage, voir 6.3.3 et 6.2.1.4.

4.6.5.2 Parties internes

Le *BDM/CDM/PDS* et ses parties de *composant* ne doivent pas dépasser les limites de température du Tableau 17 lorsqu'il est soumis à l'essai selon les caractéristiques assignées du *BDM/CDM/PDS* spécifiées en 4.9.

Tableau 17 – Températures maximales totales mesurées pour les *composants* et les matériaux internes

	Matériaux et *composants*	**Méthode de thermocouple** °C	**Méthode de l'élévation de la résistance** °C
1	Conducteurs isolés en caoutchouc ou thermoplastique [a]	75	--
2	*Bornes pour câblage externe* et autres parties qui peuvent entrer en contact avec l'*isolation* du câblage externe [b]	[b]	--
3	Bus et barrettes ou barres de raccordement	[c]	--
4	*Systèmes d'isolation* sur *composants* magnétiques [d]		
	Classe A (105)	105	125
	Classe E (120)	120	135
	Classe B (130)	125	145
	Classe F (155)	135	155
	Classe H (180)	155	175
	Classe N (200)	175	195
	Classe R (220)	195	215
5	Composition phénolique [a]	165	--
6	Sur matériau résistant nu	415	--
7	Condensateur	[f]	--
8	Dispositifs électroniques de puissance	[g]	--
9	Cartes de circuit imprimé	[h]	--
10	*Composants* pontant au moins la *protection principale*	[f]	--
11	Liquide de refroidissement	[i]	--

NOTE Aux États-Unis, les *bornes pour câblage externe* doivent être marquées uniquement pour les câbles de 60, 75 ou 60/75 °C et leur échauffement ne doit pas être supérieur à 15 °C au-dessus de la température nominale la plus basse de l'isolation, sauf pour les bornes marquées AL&Cu, qui ne doivent pas dépasser 75 °C.

[a] La limitation sur les compositions à base de phénol et sur l'*isolation* en caoutchouc et thermoplastique ne s'applique pas aux composants qui ont été examinés et qui ont satisfait aux exigences pour des températures supérieures.

[b] Il convient que la température maximale de la borne ne dépasse pas la température nominale de la borne et de l'*isolation* du conducteur ou du câble spécifiée par le fabricant (voir 6.3.7.4.2 c)).

[c] Les températures maximales admises sont déterminées par les limitations de température du matériau de support ou de l'*isolation* des câbles ou d'autres *composants*. Une température maximale de 140 °C est recommandée.

[d] Les températures maximales sur l'*isolation* des *composants* magnétiques partent de l'hypothèse que des thermocouples sont appliqués sur la surface des bobines, et donc plus sur les points chauds. La méthode de résistance électrique donne des mesurages de la température moyenne du câblage.

[e] Non utilisé dans le présent tableau.

[f] Pour un *composant*, il convient de ne pas dépasser la température maximale spécifiée par le fabricant.

[g] Il convient que la température maximale du boîtier soit celle du boîtier pour la dissipation de puissance appliquée spécifiée par le fabricant des dispositifs électroniques de puissance.

[h] La température maximale de fonctionnement de la carte de circuit imprimé ne doit pas être dépassée.

[i] Il convient de ne pas dépasser la température maximale du liquide de refroidissement spécifiée par le fabricant du liquide ou déterminée à partir des caractéristiques connues du liquide.

La méthode de résistance électrique pour les mesurages de température comme cela est spécifié dans le Tableau 17 consiste à calculer l'échauffement d'un enroulement en utilisant la formule suivante:

$$\Delta t = \frac{r2}{r1}(k + t1) - (k + t2)$$

où

Δt est l'échauffement;

r_1 est la résistance au début de l'essai (ohms);

r_2 est la résistance à la fin de l'essai (ohms);

t_1 est la *température ambiante* au début de l'essai (ºC);

t_2 est la *température ambiante* à la fin de l'essai (ºC);

k a pour valeur 234,5 °C pour le cuivre, 225,0 °C pour un conducteur électrique en aluminium de niveau (EC); les valeurs de la constante pour les autres conducteurs doivent être déterminées.

NOTE La constante k est l'opposée de la température à laquelle la résistance du métal atteint la valeur zéro si elle décroit linéairement.

Les limites de température du Tableau 17 doivent être comparées à l'échauffement décalé de la *température ambiante* maximale du *BDM/CDM/PDS*.

4.6.5.3 *Parties accessibles* du *BDM/CDM/PDS*

La température maximale doit être conforme au Tableau 18 afin d'empêcher

- les brûlures en cas de contact des *parties accessibles* du *BDM/CDM/PDS*,
- les brûlures pendant le fonctionnement du *BDM/CDM/PDS*, et
- la dégradation à long terme des matériaux de construction en contact avec le *BDM/CDM/PDS.*

Il est admis que les *parties accessibles*, dont il est exigé qu'elles soient chaudes dans le cadre de leur fonction prévue (les radiateurs, par exemple) peuvent présenter des températures atteignant 150 °C, si elles ne sont pas en contact avec des matériaux de construction et sont marquées avec l'avertissement indiqué en 6.4.4.

Pour les *BDM/CDM/PDS* uniquement destinés à être utilisés dans une *zone d'accès limité* ou les *BDM/CDM* de *type ouvert*, la température des *parties accessibles* peut dépasser 150 °C et doit être marquée selon 6.4.4.

Si la température à la surface du *BDM/CDM/PDS* dépasse la limite du Tableau 18 pour la surface de montage dans les conditions normales de fonctionnement, la construction doit être telle que

a) la surface de montage ne doit pas atteindre une température supérieure à la limite spécifiée dans le Tableau 18 pendant l'essai de température, ou

b) le manuel d'installation doit contenir un avertissement relatif à l'installation du *BDM/CDM/PDS* sur un matériau non combustible. Pour le marquage, voir 6.3.5.

Tableau 18 – Températures maximales mesurées des *parties accessibles* du *BDM/CDM/PDS*

Partie	Limites °C					
	Métal (revêtu) [a]				Verre, porcelaine et matériau vitreux	Plastique et caoutchouc
	1	2	3	4		
Dispositifs manipulés par un opérateur (boutons, poignées, interrupteurs, afficheurs, etc.) qui sont tenus en permanence en condition normale et en *condition de premier défaut* (environ 10 s)	55	55	55	60	65	70
Dispositifs manipulés par un opérateur (boutons, poignées, interrupteurs, afficheurs, etc.) qui sont tenus pendant de courtes périodes uniquement en condition normale et en *condition de premier défaut* (environ 1 s)	60	70	65	85	75	80
Parties accessibles de l'*enveloppe* susceptibles d'être touchées (environ 1 s)	65	75	70	90	80	85
Surface de montage	90					

NOTE 1 Dans le Tableau 18, les valeurs correspondant aux *parties accessibles* sont issues du Guide IEC 117 (seuil de brûlure). Pour un contact de courte durée avec des dispositifs manipulés par un opérateur, les valeurs ont été réduites de 5 °C pour prévoir une certaine marge. Le Guide IEC 117 donne également des valeurs de seuil de brûlure pour d'autres revêtements ou matériaux.

NOTE 2 Les principales figures du Guide IEC 117 sont reproduites à l'Annex J à titre informatif.

[a] Revêtement des surfaces métalliques:

1: aucun (métal nu)

2: laque ou vernis (minimum 50 µm)

3: émail vitrifié (minimum 160 µm) / surfaces peintes avec de la poudre (minimum 60 µm)

4: polyamide 11 ou 12 (minimum 400 µm)

4.7 Protection contre les dangers mécaniques

4.7.1 Généralités

La défaillance de n'importe quel *composant* à l'intérieur du *BDM/CDM/PDS* ne doit pas libérer l'énergie suffisante pour entraîner des dangers, par exemple l'expulsion de matière à l'intérieur d'une zone occupée par le personnel.

Une défaillance mécanique provoquée par des facteurs de vitesse critique ou des problèmes de torsion peuvent créer un danger pour le personnel de production. Ces considérations s'appliquent à tous les *BDM/CDM/PDS*, bien que les dangers augmentent de façon significative avec l'augmentation de la dimension du *BDM/CDM/PDS*, comme c'est le cas avec les *BDM/CDM/PDS haute tension*. Comme ces sujets dépendent de l'application, il n'est pas possible d'inclure des exigences spécifiques dans le présent document.

4.7.2 Vitesse de torsion critique

S'il y a lieu, il convient qu'une concertation s'établisse entre le fabricant des *BDM/CDM/PDS*, celui du matériel entraîné, l'installateur et l'utilisateur au sujet de toutes les considérations de vitesse de torsion critique anticipées (par exemple si une résonance mécanique peut survenir).

Pour le marquage, voir 6.3.10.3.

4.7.3 Analyse du couple transitoire

L'analyse des couples transitoires est un outil de conception précieux pour vérifier les contraintes de torsion sur toute la chaîne mécanique du *PDS*. Par exemple, les conditions de fonctionnement suivantes sont concernées:

- le démarrage;
- le court-circuit en monophasé ou en triphasé aux bornes d'un moteur à courant alternatif;
- l'impact de la défaillance possible de commutation d'un *BDM/CDM* à courant alternatif;
- l'impact des *composants* harmoniques du couple d'un *BDM/CDM* à courant alternatif;
- le court-circuit sur les bornes de l'induit d'un moteur à courant continu;
- la perte d'alimentation de l'inducteur dans un *BDM/CDM* à courant continu.

Un *BDM/CDM/PDS* ne doit pas intégrer de dispositif de protection contre les *surintensités* dans un circuit d'alimentation de l'inducteur du moteur, sauf si le *BDM/CDM/PDS* intègre un détecteur de perte de courant de champ ou de tension de champ et empêche la survitesse provoquée par la perte de champ.

Si cela est approprié, il convient qu'il y ait concertation avec le fournisseur du matériel entraîné et que les informations exigées par 6.3.10.4 soient fournies.

4.7.4 Exigences spécifiques pour le *BDM/CDM/PDS* refroidi par liquide

4.7.4.1 Généralités

Le cas échéant, le *BDM/CDM/PDS* est son *système* de refroidissement, qui utilise un réfrigérant liquide pour éliminer la chaleur, doit satisfaire aux exigences de 4.7.4.3.2 à 4.7.4.3.8.

Les systèmes de refroidissement par caloduc étanche, utilisés pour transférer la chaleur d'un *composant* chaud vers un radiateur, ne sont pas considérés comme des systèmes de refroidissement par liquide dans le présent document. Toutefois, la défaillance possible de tels *composants* doit être prise en considération pendant l'analyse du circuit du 4.2.

4.7.4.2 Liquide de refroidissement

Le liquide de refroidissement spécifié (voir 6.2) doit être adapté aux *températures ambiantes* prévues pendant le stockage et le fonctionnement. La température du liquide de refroidissement en fonctionnement ne doit pas dépasser la limite spécifiée dans le Tableau 17 et les contraintes environnementales du 4.9.

Le liquide de refroidissement utilisé dans un *système* de refroidissement doit être un réfrigérant prévu à cet effet (de l'eau et/ou de l'eau déminéralisée et/ou du glycol et/ou des huiles synthétiques non inflammables, par exemple).

La conformité est vérifiée par l'*inspection visuelle* du 5.2.1 des *composants* et des fiches techniques des matériaux, et par les essais du 5.2.3.10.

NOTE Les liquides de refroidissement inflammables utilisés dans les *systèmes* de refroidissement ne sont pas couverts par le présent document.

4.7.4.3 Exigences de la conception

4.7.4.3.1 Généralités

Les *composants* du *système* de confinement du liquide doivent être compatibles avec le liquide à utiliser.

Les *BDM/CDM/PDS* qui utilisent des liquides doivent être construits de sorte qu'une concentration dangereuse de ces matériaux ou qu'un danger au sens du présent document, par condensation, vaporisation, fuite, déversement ou corrosion soit improbable dans les conditions normales de fonctionnement, pendant le stockage, pendant le remplissage ou pendant le vidage.

La conformité est vérifiée par l'*inspection visuelle* du 5.2.1 des *composants* et des fiches techniques des matériaux.

4.7.4.3.2 Résistance à la corrosion

Tous les *composants* des *systèmes* de refroidissement doivent convenir au liquide de refroidissement spécifié. Ils doivent résister à la corrosion et ne doivent pas se corroder à l’issue d’une exposition prolongée au liquide de refroidissement et/ou à l'air.

La conformité est vérifiée par l'*inspection visuelle* du 5.2.1 des *composants* et des fiches techniques des matériaux.

4.7.4.3.3 Tuyauterie, durites et joints d’étanchéité

La tuyauterie, les durites et les joints d’étanchéité du *système* de refroidissement doivent être conçus pour empêcher les fuites pendant les excursions de pression au cours de la *durée de vie prévue* du *BDM/CDM/PDS*. Tout le *système* de refroidissement, tuyauterie comprise, doit satisfaire aux exigences de l’essai de pression hydrostatique du 5.2.7.

Tuyauterie, aussi bien protégée que non protégée, utilisée pour relier les *composants* contenant le réfrigérant doit satisfaire aux exigences d'épaisseur minimale indiquées dans le Tableau 19.

Tableau 19 – Épaisseur de paroi minimale de la tuyauterie

Diamètre extérieur		Épaisseur de paroi minimale [a] mm (pouce)					
		Cuivre				Acier	
mm	(pouce)	Protégée		Non protégée			
6,35	(1/4)	0,62	(0,024 5)	0,67	(0,026 5)	0,64	(0,025)
7,94	(5/16)	0,62	(0,024 5)	0,72	(0,028 5)	0,64	(0,025)
9,53	(3/8)	0,62	(0,024 5)	0,72	(0,028 5)	0,64	(0,025)
12,70	(1/2)	0,62	(0,024 5)	0,72	(0,028 5)	0,64	(0,025)
15,88	(5/8)	0,80	(0,031 5)	0,80	(0,031 5)	0,81	(0,025)
19,05	(3/4)	0,80	(0,031 5)	0,98	(0,038 5)	0,81	(0,032)
22,23	(7/8)	1,04	(0,041 0)	1,04	(0,041 0)	1,17	(0,032)
25,40	(1)	1,17	(0,046 0)	1,17	(0,046 0)	1,17	(0,046)
28,58	(1-1/8)	1,17	(0,046 0)	1,17	(0,046 0)	1,17	(0,046)
31,75	(1-1/4)	1,28	(0,050 5)	1,28	(0,050 5)	1,17	(0,046)
34,93	(1-3/8)	1,28	(0,050 5)	1,28	(0,050 5)	1,58	(0,046)
38,10	(1-1/2)	1,41	(0,055 5)	1,41	(0,055 5)	1,58	(0,062)
41,3	(1-5/8)	1,410	(0,055 5)	1,410	(0,055 5)	–	(0,062)
54,0	(2-1/8)	1,626	(0,064 0)	1,626	(0,064 0)	–	–
66,7	(2-5/8)	1,880	(0,074 0)	1,880	(0,074 0)	–	–

NOTE "Protégée" implique que la tuyauterie est protégée par l'armoire ou l'assemblage, de manière à éviter les dommages imprévus provoqués des objets (des outils qui tombent sur la tuyauterie ou qui la percutent pendant la manipulation et après l'installation de l'unité, par exemple).

Cette protection peut se présenter sous la forme de cloisons, de canaux, de brides, de métal perforé ou de moyens équivalents. Si une armoire est utilisée pour l'*installation* prévue d'une unité, la tuyauterie est considérée comme étant protégée. La tuyauterie ne faisant pas l'objet de ce type de protection est considérée comme n'étant pas protégée.

[a] L'épaisseur de paroi nominale de la tuyauterie doit être supérieure à l'épaisseur indiquée pour maintenir l'épaisseur de paroi minimale.

4.7.4.3.4 Disposition pour la condensation

Lorsqu'une condensation interne se produit dans des conditions normales de fonctionnement ou la maintenance, des mesures doivent être prises pour empêcher la dégradation de l'*isolation*. Voir 4.12.8.

4.7.4.3.5 Conductivité du liquide de refroidissement

Lorsque du liquide de refroidissement est intentionnellement en contact avec les *parties actives* (par exemple des radiateurs non connectés à la terre), la conductivité du liquide de refroidissement doit être continuellement surveillée et contrôlée, pour éviter une circulation de courant dangereuse dans le liquide de refroidissement.

4.7.4.3.6 Fuite du liquide de refroidissement

Des mesures doivent être prises pour empêcher une fuite du liquide de refroidissement sur les *parties actives* par suite de conditions normales de fonctionnement, d'une réparation, du desserrage ou du détachement des tuyaux ou d'autres parties du système de refroidissement pendant *la durée de vie prévue*.

Si un mécanisme limiteur de pression est fourni, il doit être situé de telle manière qu’aucune fuite de liquide de refroidissement ne se produise sur les *parties actives* lorsqu’il est activé.

Le mouillage des *parties actives* ou de l'*isolation électrique* doit être évité pendant une fuite de liquide de refroidissement.

La conformité est vérifiée par l'*inspection visuelle* du 5.2.1.

4.7.4.3.7 Perte du liquide de refroidissement

La perte du liquide de refroidissement dans le *système* de refroidissement ne doit pas entraîner de dangers thermiques, d’explosion ou de danger de choc électrique. Les exigences de l’essai concernant la perte de liquide de refroidissement du 5.2.4.13.4 doivent être satisfaites.

4.7.4.3.8 Exigences d’*isolation* pour les tuyaux du liquide de refroidissement

Lorsque le liquide de refroidissement est intentionnellement en contact avec des *parties actives* (par exemple des radiateurs non connectés à la terre), les tuyaux du liquide de refroidissement doivent être considérés comme faisant partie du *système d’isolation*. En fonction de l'emplacement de leur emplacement, les tuyaux, doivent satisfaire aux exigences applicables du 4.4.7 pour l’*isolation fonctionnelle*, l’*isolation principale*, l’*isolation supplémentaire* et l’*isolation renforcée.*

4.7.5 Dangers mécaniques provenant des parties rotatives

4.7.5.1 Généralités

Les parties rotatives ne doivent présenter aucun danger.

4.7.5.2 Dangers mécaniques provenant du ventilateur

Les ventilateurs et leurs pales ne doivent pas provoquer de blessures dans les conditions de fonctionnement normal et pendant l'entretien et la maintenance. Pour plus d'informations, voir l'IEC 62368-1:2018, 8.2.

NOTE 1 Pour la protection contre la douleur, voir l'IEC 62368-1.

NOTE 2 Le terme "blessure" signifie que l'intervention d'un médecin ou des urgences peut s'avérer nécessaire.

Les pales de ventilateur dangereuses doivent être protégées par une *enveloppe* ou des barrières satisfaisant le niveau IPXXB. Voir l'essai du 5.2.2.2.

Aucune protection des pales de ventilateur n'est exigée s'il peut être vérifié par les formules ci-dessous que leur contact ne provoque aucune blessure:

- les pales de ventilateur en plastique conformes l'équation $\frac{N}{44\,000}+\frac{K}{7\,200}\leq 1$;
- les autres pales de ventilateur conformes l'équation $\frac{N}{22\,000}+\frac{K}{3\,600}\leq 1$.

Le coefficient K est déterminé à partir de la formule:

$$K = 6 \times 10^{-7} \times m \times r^2 \times N^2$$

où

m est la masse (kg) de la partie mobile du ventilateur (pale, arbre et rotor);

r est le rayon (mm) de la pale de ventilateur entre à l'axe du moteur (arbre) et le bout de la zone extérieure susceptible d'être touchée,

N est la vitesse de rotation (r/min) de la pale de ventilateur. La vitesse maximale du ventilateur dans l'application doit être prise en compte.

4.7.5.3 Parties expulsées

Toutes les parties mobiles doivent être correctement fixées et protégées selon les exigences du 4.2.

Par exemple

- protection par une *enveloppe*, une barrière ou un protecteur, et
- utilisation de pratiques mécaniques habituelles (rondelles de verrouillage, matériel autorétentif, serrage au couple correct du matériel, rivets, soudage, etc.).

La conformité est vérifiée par l'inspection visuelle du 5.2.1.

4.7.6 Bords aiguisés

Les bords, projections, coins, orifices, protecteurs, poignées et éléments similaires auxquels l'opérateur a accès doivent être lisses et arrondis de manière à ne pas blesser pendant l'installation, les conditions de fonctionnement normal et la maintenance de l'équipement.

La conformité est vérifiée par l'essai de type d'inspection visuelle du 5.2.1 et, le cas échéant, par l'application d'un objet dont la dimension, la forme et la dureté sont représentatives de celles d'un doigt, afin de vérifier la présence d'abrasion ou de coupures.

NOTE Un mode opératoire acceptable est décrit dans l'IEC TR 62854:2014 ou l'UL 1439.

4.8 *BDM/CDM/PDS à plusieurs sources d'alimentation*

4.8.1 Généralités

Si le *BDM/CDM/PDS* est équipé de plusieurs *accès* d'alimentation (avec des tensions ou fréquences différentes ou en tant qu'alimentation de secours, par exemple), la conception doit être telle que toutes les conditions suivantes a), b) et c) sont satisfaites:

a) des moyens de connexion séparés sont prévus pour chaque *accès*;

b) les prises d'alimentation, le cas échéant, ne sont pas interchangeables si un branchement incorrect peut provoquer un danger;

c) aucun danger, au sens du présent document, ne doit être présent dans des conditions normales de fonctionnement ou dans les *conditions de premier défaut* en raison de la présence de plusieurs sources d'alimentation. Des actions telles que la connexion et la déconnexion ou la mise sous tension et hors tension d'une alimentation sont considérées comme une condition normale de fonctionnement.

Voir également 4.4.7.1.7.

La conformité est vérifiée par l'évaluation du 4.2.

Pour le marquage, voir 6.5.5.

Les éléments suivants sont des exemples de types de dangers à prendre en considération.

1) Rétroalimentation – la présence de tension ou d'énergie renvoyée à l'une des bornes d'entrée du *BDM/CDM/PDS* à partir de sa source ou par un chemin de fuite, y compris le mode de récupération.
2) Îlotage involontaire – lorsque le *BDM/CDM/PDS* continue de fournir la puissance de sortie lorsque la puissance d'entrée est retirée des *accès* de puissance d'entrée.
3) Les niveaux de *courant de contact* peuvent être supérieurs lorsque plusieurs sources sont connectées en même temps (s'il s'agit d'une condition normale de fonctionnement pour le *BDM/CDM/PDS*).
4) Les dangers résultant d'une ou de plusieurs sources endommagées (un générateur, par exemple) en raison de l'énergie provenant d'une autre source (le *réseau*, par exemple).
5) Les dommages causés au câblage en raison de courants plus élevés que ceux pour lesquels le câblage a été conçu provenant d'une autre source.

4.8.2 Partage de liaison à courant continu *basse tension*

Le paragraphe 4.8.2 définit des exigences spécifiques supplémentaires lorsqu’au moins deux *BDM/CDM* de type de source de tension partagent leur source de tension continue interne.

Si au moins deux *BDM/CDM* d'un *PDS* sont destinés à être installés dans la même *enveloppe* ou à former la même *enveloppe*, une analyse de circuit *PDS* pour connaître les effets de la défaillance d'un *composant* doit être réalisée selon 4.2, et un essai doit être mené en conséquence pour l'ensemble complet.

Si au moins deux *BDM/CDM* d'un *PDS* sont destinés à être installés dans des *enveloppe*s distinctes, chaque accès de puissance en courant continu connecté à la liaison à courant continu doit être protégé contre les *surintensités* externes. Une analyse de circuit *PDS* pour connaître les effets d'une défaillance d'un *composant* doit être réalisée selon 4.2 pour chaque *BDM/CDM*, et un essai doit être réalisé en conséquence.

NOTE Une protection de la liaison à courant continu contre le courant de défaut à la terre est en général prévue par le *système* de distribution en courant continu.

4.9 Protection contre les contraintes environnementales

4.9.1 Généralités

Les *BDM/CDM/PDS* ne doivent présenter aucun danger par suite des contraintes environnementales spécifiées pour lesquelles l'équipement est marqué. Sur la base des recommandations de l’IEC 60721-3-0:1984 et de l’IEC 60721-3-0:1984/AMD1:1987[2], au moins, Les *BDM/CDM/PDS* doivent satisfaire aux exigences environnementales du Tableau 20 et doivent le démontrer par les essais d'environnement du 5.2.6.

NOTE 1 Les exigences d’essai du 5.2.6 sont fondées sur les recommandations de l’IEC TR 60721-4-3:2001, de l’IEC TR 60721-4-3:2001/AMD1:2003, et sur l’IEC TR 60721-4-4:2001 et l’IEC TR 60721-4-4:2001/AMD1:2003.

Des exigences plus strictes que celles du Tableau 20 peuvent être spécifiées par le fabricant, auquel cas les essais les moins contraignants du présent document doivent être remplacés par un essai plus sévère exigé pour le niveau supérieur.

NOTE 2 Un environnement corrosif intérieur peut être un exemple d'exigence plus stricte.

[2] Cette publication a été retirée.

Le fabricant doit spécifier les conditions de service suivantes pour le fonctionnement, le stockage et le transport, selon le cas:

- température du liquide de refroidissement (min./max.);
- *température ambiante* (min./max.);
- humidité (min./max.);
- degré de pollution;
- vibrations;
- altitude pour des considérations thermiques, si adaptée à un fonctionnement au-dessus de 1 000 m;
- altitude pour des considérations relatives à la coordination de l'*isolation*, si adaptée à un fonctionnement au-dessus de 2 000 m (maximum).

NOTE 3 Les catégories environnementales spécifiées dans l'IEC 60721 (toutes les parties) peuvent être utilisées quand cela est approprié.

Le fabricant doit indiquer les conditions de service environnementales pour le *BDM/CDM/PDS* conformément au Tableau 20.

Pour le marquage, voir 6.3.3 et 6.3.6.3.

NOTE 4 Aux États-Unis et au Canada, la température ambiante retenue est comprise entre 0 °C et 40 °C, sauf indication contraire.

Tableau 20 – Conditions de service environnementales

Condition	Intérieur sans condition	Extérieur sans condition
Norme	IEC 60721-3-3:1994, IEC 60721-3-3:1994/AMD1:1995 et IEC 60721-3-3:1994/AMD2:1996[3]	IEC 60721-3-4:2019
Climatique	Classe 3K3	Classe 4K6
Basse température	+5 °C	–20 °C
Haute température	40 °C	55 °C
Faible humidité	5 % R.H.	4 % R.H.
Humidité élevée	85 % R.H.	100 % R.H.
condensation	Non admise	Admise
Degré de pollution	3 [b]	4 [c]
Dermatite liée à l'humidité [d]	Mouillé à l'eau [a]	Mouillé à l'eau salée [a]
Substances chimiquement actives	Classe 3C1 (pas de brouillard salin)	Classe 4C2 (brouillard salin) [a]
Substances mécaniquement actives	Class 3S1 (aucune exigence)	Class 4S2 (poussière et sable)
Mécanique	Class 3M1 (vibration: 1 m/s^2)	Class 4M1 (vibration: 1 m/s^2)
Biologique	Class 3B1 (aucune exigence)	Class 4B2 (moisissure/champignons/ rongeurs/termites)
Résistance aux ultraviolets	Aucune exigence	4.12.9

[a] S'il est assuré que l'équipement ne va pas être amené à être utilisé dans des conditions mouillées ou mouillées à l'eau salée, le fabricant peut choisir d'assigner l'équipement pour des conditions moins sévères. Dans ce cas, les caractéristiques assignées doivent être indiquées dans la documentation, conformément à 6.3.3 et 6.2.1.4.

[b] Le degré de pollution 2 peut être fourni si les conditions de 4.4.7.1.3 sont satisfaites.

[c] Le degré de pollution 2 ou le degré de pollution 3 peut être fourni si l'*enveloppe* assure une protection suffisante contre la pollution conductrice et si les conditions de 4.4.7.1.3 sont satisfaites.

[d] Cette exigence est ajoutée au présent tableau compte tenu de l'interaction entre les utilisateurs et le *BDM/CDM/PDS* lors du choix de la *CTD As* applicable. Par exemple, la peau sèche de la main devient humide au contact d'un *BDM/CDM/PDS* mouillé.

Pour une utilisation dans un environnement extérieur sans condition, lorsqu'une condensation interne ne peut pas être exclue, un ou plusieurs des éléments suivants a), b) ou c) est exigé:

a) des mesures doivent être prévues dans le *BDM/CDM/PDS* pour empêcher la mise sous tension ou le fonctionnement en présence de condensation;
b) l'essai de chaleur humide (cyclage) doit être réalisé, voir 5.2.6.3.5;
c) un marquage est exigé pour spécifier le chauffage, voir 6.3.3 d).

La conformité est vérifiée par l'essai du 5.2.6.

[3] Ce document et les annexes ont été retirés.

4.9.2 Protection contre la corrosion

Les parties en fer et en acier doivent être protégées contre la corrosion par émaillage, galvanisation, plaquage ou d'autres moyens équivalents. Les éléments suivants ne sont pas concernés:

1) parties dans lesquelles ce type de protection est irréalisable;
2) parties dans lesquelles la corrosion ne présente pas de risque de feu, de choc électrique ou de blessure.

4.10 Protection contre les dangers de bruit acoustique excessif

4.10.1 Généralités

Le *BDM/CDM/PDS* doit assurer la protection contre les effets du bruit acoustique excessif. Des essais de conformité sont réalisés si le *BDM/CDM/PDS* est susceptible de provoquer ce type de danger.

4.10.2 Niveau de bruit acoustique

Si le *BDM/CDM/PDS* génère du bruit dont le niveau peut être dangereux, le bruit doit être mesuré afin de déterminer le niveau de bruit maximal que le *BDM/CDM/PDS* peut produire (les sons provenant d'alarmes sont exclus). Si la pression acoustique mesurée dépasse 70 dBA, le fabricant doit donner des informations relatives aux effets du bruit acoustique.

La conformité est vérifiée par l'essai du 5.2.2.9.

Pour le marquage, voir 6.4.1 e).

4.11 Câblage et raccordements

4.11.1 Généralités

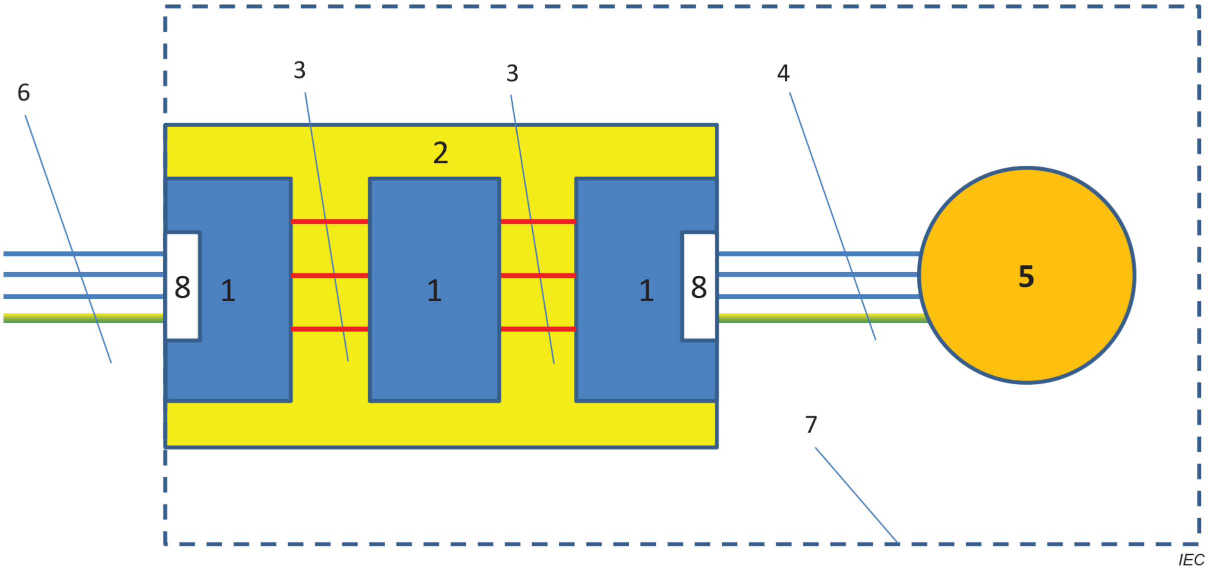
Le câblage et les interconnexions du *BDM/CDM/PDS* doivent être protégés contre les dommages mécaniques pendant l'installation et l'utilisation. L'*isolation*, les conducteurs et le cheminement de tous les fils électriques du *BDM/CDM/PDS* doivent être adaptés aux conditions d'utilisation électriques, mécaniques, thermiques et environnementales.

Les conducteurs pouvant se toucher doivent posséder un niveau d'isolation répondant aux exigences de la *CTD* des circuits correspondants conformément au Tableau 3.

La compatibilité avec 4.11.2 à 4.11.12 doit être vérifiée par une *inspection visuelle* du 5.2.1 de toute la construction et de toutes les fiches techniques, selon le cas.

Pour le marquage, voir 6.3.7.1, 6.3.7.2, 6.3.7.3 et 6.3.7.4.

Un exemple d'interconnexions à l'intérieur du *BDM/CDM* et entre les parties du *PDS* est présenté à la Figure 7 et à la Figure 8.



Légende:

1 partie 1 à n du *BDM* ou du *CDM*

2 *BDM* ou *CDM*

3 interconnexion interne du *BDM* ou du *CDM*

4 interconnexion entre les parties d'un *PDS*

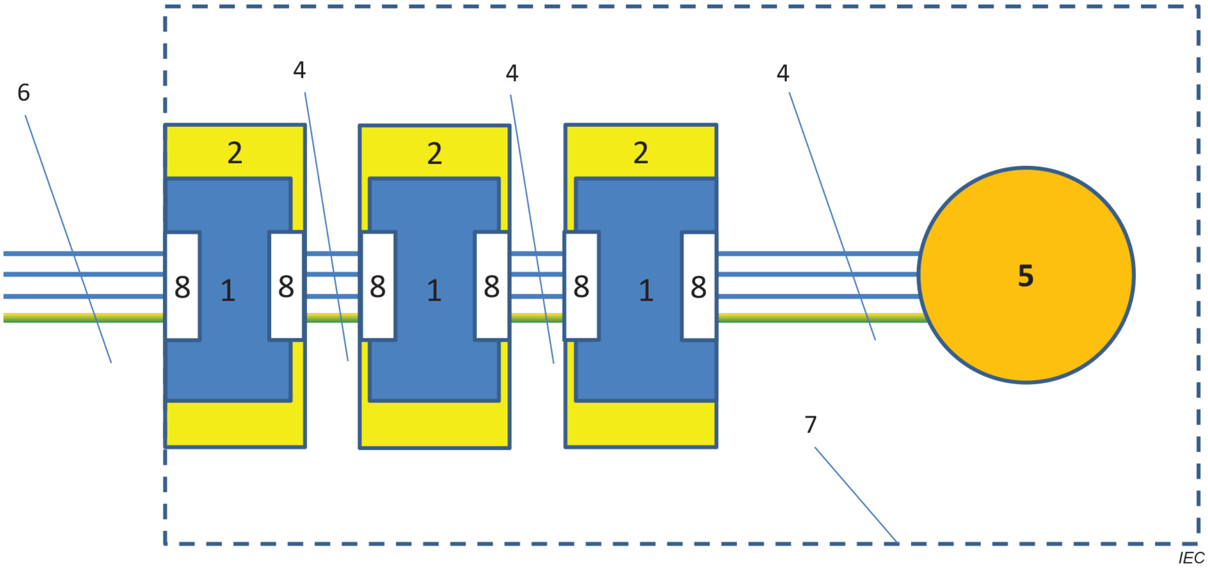
5 charge (par exemple moteur, résistance de freinage)

6 conducteurs d'alimentation comme partie intégrante de l'*installation*

7 *PDS*

8 *borne pour câblage externe*

Figure 7 – Exemple d'interconnexions à l'intérieur du *BDM/CDM* et entre les parties du *PDS*



Légende:

1 partie 1 à n du *BDM* ou du *CDM*

2 *BDM* ou *CDM*

3 non utilisé

4 interconnexion entre les parties d'un *PDS*

5 charge (par exemple moteur, résistance de freinage)

6 conducteurs d'alimentation comme partie intégrante de l'*installation*

7 *PDS*

8 *borne pour câblage externe*

Figure 8 – Exemple d'interconnexions entre les parties du *PDS* (parties du *BDM/CDM* séparées par le câblage externe)

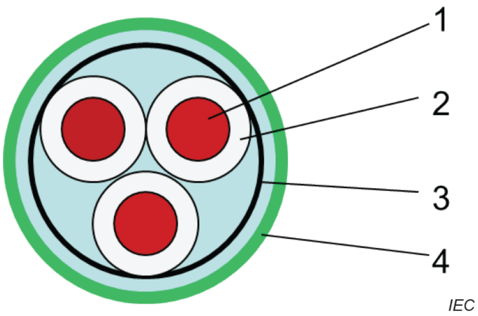
4.11.2 *Isolation* des conducteurs

4.11.2.1 Généralités

Les conducteurs doivent assurer l'*isolation* conformément aux exigences du présent document. Cela peut être obtenu par les *distances d'isolement* et les *lignes de fuite* ou par l'*isolation solide*.

Les conducteurs non isolés (les bus de raccordement, par exemple) doivent être installés pour satisfaire aux exigences appropriées en matière de *distances d'isolement* et de *lignes de fuite* à l'intérieur du circuit et par rapport à d'autres circuits pour la *CTD* de la tension concernée selon le Tableau 8 et le Tableau 10.

Un exemple de disposition de conducteurs isolés dans un câble est présenté à la Figure 9.



Légende

1 conducteur

2 *isolation* du conducteur (*protection principale*)

3 blindage (facultatif)

4 gaine non métallique du câble (*protection en cas de défaut*)

Figure 9 – Exemple de disposition de conducteurs isolés dans un câble

Les normes de produits pour les conducteurs et les câbles ne spécifient pas la capacité de *tension de tenue aux chocs* ni l'aptitude par rapport à la décharge partielle.

Toutefois, le présent document considère que la combinaison d'une *isolation* des conducteurs individuels et d'une gaine non métallique du câble, qu'un blindage fasse partie ou non de la construction, fournit une *protection renforcée* selon 4.4.5, si le câble satisfait à toutes les exigences suivantes a), b) et c):

a) le câble satisfait à la norme de produits applicable pour les câbles;
b) la tension assignée du conducteur ou du câble isolé ne doit pas être inférieure à la tension assignée à l'intérieur du circuit et par rapport aux autres circuits;
c) la tension d'essai des conducteurs isolés doit satisfaire au Tableau 31 ou au Tableau 33 applicable pour les circuits *basse tension* et au Tableau 32 pour les circuits haute tension.

L'*isolation* du conducteur est considérée comme une *protection principale* et la gaine non métallique comme une *protection en cas de défaut*.

NOTE Pour plus d'informations, voir l'IEC 60364-4-41:2005, Article B.3.

4.11.2.2 *Système* de câblage accessible

Les *systèmes* de câblage *basse tension* à l'extérieur de l'*enveloppe* sont considérés comme satisfaisant aux exigences du 4.4.3.3, si une protection mécanique adaptée des conducteurs isolés est assurée par l'un au moins des éléments suivants:

a) une gaine non métallique du câble, à condition que les exigences a), b) et c) du 4.11.2.1 soient satisfaites;
b) un conducteur isolé assurant l'*isolation principale* et la *protection en cas de défaut* est fourni par
   1) un fourreau à câble non métallique conforme à l'IEC 61084 (toutes les parties),
   2) un conduit non métallique conforme à l'IEC 61386 (toutes les parties) ou un équivalent,
   3) un fourreau à câble ou un conduit métallique, à condition que les parties métalliques soient reliées au *système* de *liaison équipotentielle de protection* et satisfassent à 4.4.4.2.2, ou
   4) un conducteur isolé conforme à une norme de produits sur les conducteurs isolés applicable et assurant une *isolation renforcée*.

4.11.2.3 Conducteurs de circuits différents

Lorsque des conducteurs de circuits différents sont présents à l'intérieur d'un câble multiconducteur ou occupent le même fourreau (conduit, *système* de goulottes, par exemple),

- ces conducteurs doivent être isolés de tous les autres conducteurs selon le Tableau 3, ou
- tous les conducteurs doivent avoir une *isolation* pour la tension la plus élevée concernée.

Si l'*isolation* s'appuie sur des *distances d'isolement* et des *lignes de fuite*, des moyens doivent être prévus pour garder les conducteurs séparés.

4.11.3 Fil multibrin

Les points de raccordement prévus doivent être disposés de façon appropriée pour interdire toute possibilité de brins de fil libres réduisant la *distance d'isolement* et les *lignes de fuite* entre les conducteurs lorsque l'installation est effectuée avec la plus grande attention.

Si un fil multibrin ou un écran multibrin est relié à une vis de serrage, une borne ou d'autres moyens de connexion, la construction doit être telle que les brins libres satisfassent aux exigences du 4.4.7.4 et du 4.4.7.5 par rapport

- aux autres *parties actives* non isolées (et n'ayant pas toujours le même potentiel que le fil), ou
- aux parties métalliques hors tension.

NOTE Ces exigences sont satisfaites si les dispositions en matière de connexion sont utilisées en intégrant les distances selon le Tableau S.23 ou le Tableau S.24 applicables.

4.11.4 Cheminement et serrage

Le perçage dans la paroi en tôle de l'*enveloppe* du *BDM/CDM/PDS* par lequel passent les fils isolés doit posséder un manchon ou œillet lisse et bien arrondi ou doit avoir une surface lisse et bien arrondie là où reposent les câbles, pour réduire tout risque d'abrasion de l'*isolation*.

Le cheminement du câblage doit éviter tous bords aiguisés ou non ébarbés, tous filetages, ailettes, parties mobiles, tiroirs et parties similaires qui abrasent l'*isolation* des fils. Le rayon de courbure minimal spécifié par le fournisseur de câble ne doit pas être dépassé.

Les bords des étriers et guides fils, métalliques ou non, utilisés pour le cheminement du câblage interne et externe fixe doivent être lisses et arrondis. L'action de blocage et la surface d'appui doivent être telles que tout frottement ou dommage de l'isolation soit impossible. Si un étrier en métal est utilisé pour des conducteurs dont l'*isolation* thermoplastique est inférieure à 0,8 mm d'épaisseur, une protection mécanique non conductrice doit être prévue.

4.11.5 Identification des conducteurs et des bornes du *réseau* et de l'*alimentation non raccordée directement au réseau*

Si l'identification des conducteurs internes, des bornes et des *bornes pour câblage externe* est considérée comme nécessaire pour la sécurité pendant l'installation et/ou la maintenance, le choix de la méthode appropriée relève de la responsabilité du fabricant de *BDM/CDM/PDS*. Des recommandations sont données dans l'IEC 60445:2021 et l'IEC 61148:2011.

Si l'identification se fait par la couleur, elle doit se faire aux extrémités et de préférence sur toute la longueur du conducteur, soit par la couleur de l'*isolation*, soit par des marqueurs de couleurs, à l'exception des conducteurs nus pour lesquels l'identification par couleur doit se faire à l'extrémité et aux points de raccordement.

Si l'identification se fait par la couleur, les couleurs verte et jaune doivent être utilisées pour la *liaison équipotentielle de protection* ou pour le ou les *conducteurs de mise à la terre de protection*. Les couleurs verte et jaune ne doivent pas servir à d'autres fins. Si un circuit comprend un conducteur de neutre identifié par la couleur, la couleur utilisée à cet effet doit être le bleu clair.

Le choix du bleu clair pour le conducteur de neutre et du vert ou du vert et jaune pour la *liaison équipotentielle de protection* ou pour le *conducteur de mise à la terre de protection* est couvert les règlements nationaux.

NOTE Aux États-Unis et au Canada, la couleur blanche est utilisée en lieu et place du bleu clair est utilisée pour le conducteur de neutre, et le vert est utilisé en lieu et place du vert et du jaune pour le *conducteur de mise à la terre de protection*.

Pour les conducteurs isolés, qui font partie d'une nappe ou d'un câble signal multifils, uniquement identifiés par la couleur, l'usage des seules couleurs vertes, jaunes et bleues est admis. Toutefois, le fabricant doit donner des informations et/ou des marquages indiquant clairement la signification du codage couleur. Cela doit également éviter toute erreur d'identification avec la mise à la terre ou d'autres *systèmes* qui peuvent souvent utiliser ces couleurs.

La borne de connexion de la borne PE doit être marquée selon 6.3.9.2.2.

4.11.6 Épissures et raccordements

Toutes les épissures et tous les raccordements doivent être assurés mécaniquement et doivent assurer la continuité électrique.

Les connexions électriques doivent être soudées, serties ou effectuées de façon sûre. Un joint soudé, autre qu'un *composant* sur une carte de circuit imprimé doit, de plus, être sécurisé mécaniquement.

Le fil multibrin ne doit pas être renforcé par une soudure lorsqu'il est fixé dans une borne qui repose uniquement sur des vis ou des moyens analogues destinés à la pression de contact.

Lorsque des connexions sont effectuées au moyen de bornes à vis, les connexions résultantes peuvent nécessiter une maintenance périodique (serrage). Une référence appropriée doit être donnée dans le manuel de maintenance (voir 6.5.1).

4.11.7 Connexions accessibles

Outre les mesures indiquées en 4.4.6.5.3, il faut assurer qu'aucune erreur d'insertion ni inversion de polarité des connecteurs ne peut générer une tension supérieure à la valeur maximale de la *CTD As* ou un autre danger sur une connexion accessible.

Les fiches du cordon d'alimentation d'un *BDM/CDM/PDS* ne doivent pas s'insérer dans les socles de prise de courant réseau des *systèmes de réseau* à des tensions supérieures à la tension assignée du *BDM/CDM/PDS*.

NOTE L'IEC TR 60083 donne des informations relatives aux fiches et aux socles de prise de courant des *systèmes de réseau*.

Les fiches et prises de réseau ne doivent pas être utilisées pour des besoins autres que la connexion d'un *réseau*. Cela s'applique, par exemple, aux sous-ensembles débrochables ou autres dispositifs débrochables qui peuvent être branchés sans l'aide d'un outil ou d'une clé ou qui sont accessibles sans utiliser d'outil ou de clé. Cela ne s'applique pas aux *BDM/CDM/PDS* destinés à être utilisés dans des *zones d'accès limité*.

Si les broches des fiches d'un *BDM/CDM/PDS* enfichable reçoivent une charge provenant d'un condensateur interne, les broches doivent être examinées selon 4.4.6.5.3 et 4.4.9.

L'essai selon 5.2.3.8 doit être réalisé, si nécessaire.

Le marquage est exigé sur le *BDM/CDM/PDS* avec les socles de prise de courant réseau comme suit:

a) si le socle de prise de courant réseau peut accepter une fiche *réseau*, il faut apposer un marquage comme cela est spécifié en 6.3.7.5;
b) si le socle de prise de courant réseau comporte un contact de borne pour un *conducteur de mise à la terre de protection*, la connexion *réseau* d'entrée dans le *BDM/CDM/PDS doit inclure un conducteur de mise à la terre de protection* connecté à une borne de *conducteur de mise à la terre de protection*.

S'il y a lieu, la non-interchangeabilité et la protection contre l'inversion de polarité des fiches et des prises doivent être confirmées par une *inspection visuelle* du 5.2.1 ainsi que par des essais d'insertion.

4.11.8 Interconnexions entre les parties d'un *PDS*

Des considérations doivent être données concernant la tension et le courant nominaux du ou des circuits et la température de l'*environnement* du câblage entre les parties de l'ensemble du *PDS*. Toutes les sections du *BDM/CDM/PDS* doivent satisfaire à l'une des exigences suivantes a), b) ou c):

a) paragraphes applicables 4.11.2 à 4.11.12;
b) IEC 60364 (toutes les parties);
c) *règles d'installation* locales.

Les assemblages de câbles et les cordons flexibles fournis pour l'interconnexion entre les parties d'un *BDM/CDM/PDS* ou entre les parties d'un *système* doivent être adaptés au service ou à l'usage auquel ils sont destinés. Pour les *BDM/CDM* sous enveloppe*, l*es câbles doivent être protégés des dommages physiques dès qu'ils sortent de l'*enveloppe* et ils doivent être fournis avec des supports d'attache (voir 4.12.6).

Le mauvais alignement des connecteurs mâles et femelles, l'insertion d'un connecteur multipoint mâle dans un connecteur femelle autre que celui destiné à le recevoir et d'autres manipulations de parties qui sont accessibles à l'opérateur ne doivent pas pouvoir provoquer de dommages mécaniques ou un risque de dangers thermiques, de chocs électriques ou de blessures.

Lorsque des câbles d'interconnexion sont terminés par une prise qui se branche sur un réceptacle situé sur une surface externe de l'*enveloppe*, il ne doit pas y avoir de risque de choc électrique au niveau des contacts accessibles, ni sur la fiche, ni sur le réceptacle, lors de la déconnexion.

Les exigences en matière d'interconnexion externe *TBTP* ou *TBTS* sont données en 4.4.6.5.3.

Aucune exigence n'est donnée concernant l'interconnexion interne.

NOTE Un circuit de *verrouillage* au câble, mettant hors tension les contacts accessibles lorsque le câble est déconnecté satisfait aux intentions de ces exigences.

Pour des informations, voir l'IEC 60204-1:2016.

4.11.9 Raccordement de l'alimentation pour les *BDM/CDM/PDS connectés en permanence*

Un *BDM/CDM/PDS* destiné à être *connecté en permanence* à l'alimentation doit pouvoir être relié au *système* de câblage en vigueur conformément aux exigences relatives à son site d'installation.

4.11.10 Raccordement de l'alimentation des *BDM/CDM/PDS* enfichables

4.11.10.1 Exigences relatives aux cordons (cordons *réseau*, par exemple)

NOTE Les exigences sont déduites de l'IEC 61010-1:2010, 6.10.1.

Les exigences suivantes s'appliquent aux cordons *réseau* non détachables et aux *cordons réseau* détachables fournis avec le *BDM/CDM/PDS* et aux raccordements analogues. Voir la Figure 10.

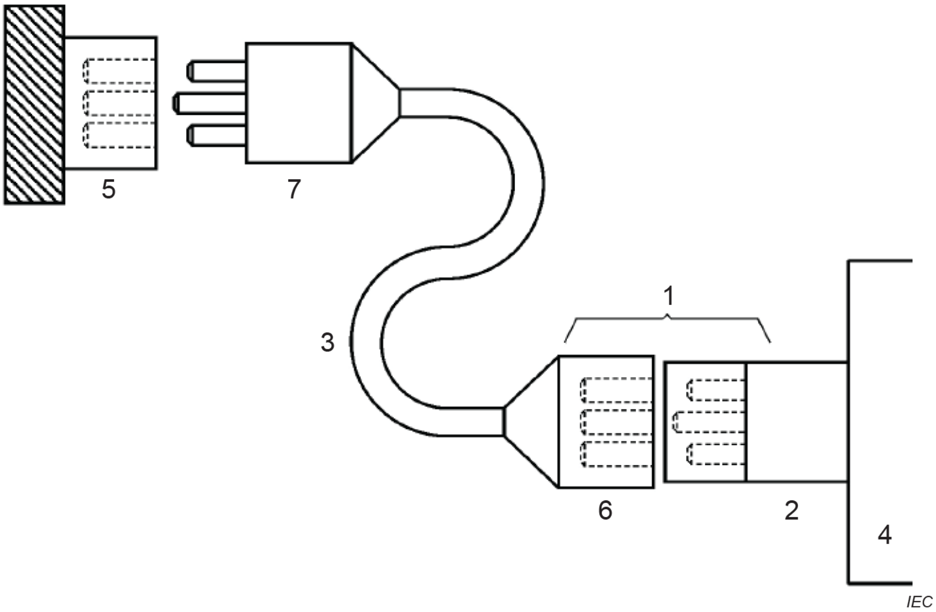
Les cordons doivent satisfaire à 4.11, selon le cas, et être adaptés au courant maximal du *BDM/CDM/PDS*.

Si un cordon est susceptible d'entrer en contact avec des parties extérieures chaudes du *BDM/CDM/PDS*, il doit être constitué d'un matériau adapté résistant à la chaleur.

Si le cordon est détachable, il doit, avec le socle de connecteur, présenter des caractéristiques assignées de température adaptées.

L'identification des conducteurs et des bornes doit être conforme à 4.11.5.

Les cordons *réseau* détachables avec les prises réseau conformes aux parties correspondantes de la série IEC 60320 doivent satisfaire aux exigences de l'IEC 60799:2018 ou doivent être assignés au moins au courant nominal des prises réseau associées au cordon.



Légende

1 connecteur

2 socle de connecteur

3 câble

4 *BDM/CDM/PDS*

5 socle de prise de courant réseau fixe

6 prise réseau

7 fiche réseau

Figure 10 – Cordons *réseau* détachables et connexions

La conformité est vérifiée par l'*inspection visuelle* du 5.2.1. Il convient d'utiliser le mesurage des dimensions, le cas échéant.

4.11.10.2 Fixation des cordons *réseau* non détachables

4.11.10.2.1 Entrée de cordon

Les cordons *réseau* doivent satisfaire à 4.11 et être protégés contre l'abrasion et les courbures importantes au point d'entrée du cordon dans le *BDM/CDM/PDS*, par l'un des moyens suivants a) ou b):

a) une entrée ou une traversée avec un orifice légèrement arrondi;

b) un protecteur de cordon souple fixé de manière fiable, constitué d'un matériau isolant dépassant l'orifice d'une valeur égale à au moins 5 fois le diamètre total d'un cordon présentant la section la plus large qui peut être installée. Pour les cordons plats, la section plus importante est considérée comme étant le diamètre total.

La conformité est vérifiée par l'*inspection visuelle* du 5.2.1. Il convient d'utiliser le mesurage des dimensions, le cas échéant.

4.11.10.2.2 Dispositif d'arrêt de traction et de torsion

Le dispositif d'arrêt de traction et de torsion doit satisfaire aux exigences et essais de support d'attache de câbles du 4.12.6.

4.11.10.2.3 Fiches et connecteurs

Les fiches et connecteurs qui raccordent le *BDM/CDM/PDS* au *réseau*, y compris les connecteurs permettant de raccorder des cordons *réseau* détachables, doivent satisfaire aux exigences correspondantes relatives aux fiches, aux *socles de prise de courant réseau* et aux connecteurs, et doivent satisfaire à h 4.11.7.

4.11.11 Bornes

4.11.11.1 Exigences de construction

Toutes les pièces des *bornes pour câblage externe* et des bornes internes qui maintiennent le contact et véhiculent le courant doivent être d'un métal ayant la solidité mécanique adéquate.

Les bornes doivent être telles que les conducteurs puissent être connectés au moyen de vis, de connexions à ressort ou d’autres moyens équivalents de façon à maintenir la pression de contact nécessaire.

Les bornes doivent être réalisées de façon telle que les conducteurs puissent être fixés entre les surfaces appropriées sans dommage significatif tant sur les conducteurs que sur les bornes.

Les bornes ne doivent pas permettre un déplacement des conducteurs ou un déplacement d’elles-mêmes ayant pour effet de nuire au bon fonctionnement du *BDM/CDM/PDS*, et l’*isolation* ne doit pas être réduite en dessous de ses valeurs assignées.

Les exigences du 4.11.11.1 sont satisfaites par l'utilisation de bornes conformes à l’IEC 60947-7 (toutes les parties).

4.11.11.2 Capacité de raccordement des bornes

Les *bornes pour câblage externe* et les bornes internes doivent accueillir l’installation de câblage spécifiée dans la documentation (voir 6.3.7.4). Il doit être possible de réaliser l’installation selon les règles de câblage applicables à l’*installation*.

Les bornes pour *accès* de puissance d'entrée et pour *accès* de puissance de sortie doivent être dimensionnées de manière à couvrir la totalité des exigences applicables suivantes:

- la dimension de fil pour 125 % du courant nominal à la température nominale:
  - le matériau prévu du conducteur (cuivre ou aluminium, par exemple);
  - la longueur de câble maximale admise;
- la dimension de fil pour le courant spécifié le plus faible du moteur destiné à être utilisé: la longueur de câble minimale admise;
- la température nominale de l'*isolation* prévue pour le conducteur;
- la *température ambiante* maximale de l'*installation* prévue du câble de moteur.

NOTE 1 Un câble long peut provoquer une chute de tension indésirable qui peut être compensée par une dimension de fil plus importante.

NOTE 2 Exemples de *températures ambiantes*: L'IEC 61439-1 et l'IEC 60204-1 exigent au moins 40° C, l'IEC 60364-5-52 exige au moins 30 °C pour toutes les *installation*s et 20 °C pour les *installation*s avec câbles enterrés.

Les bornes doivent satisfaire aux essais d’échauffement du 5.2.3.10.

Des informations relatives aux dimensions de conducteur admises doivent être données dans le manuel d'installation. Voir 6.3.7.4.2.

Les valeurs normalisées de section des conducteurs en cuivre ronds sont indiquées à l'Annex G, qui donne également la relation approximative entre les dimensions ISO métriques et les calibres AWG/MCM.

4.11.11.3 Raccordement à des conducteurs externes par des *bornes pour câblage externe*

Les *bornes pour câblage externe* des conducteurs externes doivent être facilement accessibles pendant l'installation.

Les ensembles de *bornes pour câblage externe* pour le raccordement au même *accès* d'entrée ou *accès* de sortie doivent être rassemblés.

La borne de *mise à la terre de protection* doit se trouver à proximité des *accès* d'entrée ou des *accès* de sortie, sauf en présence d'un marquage selon 6.3.9.2.2.

Pour chaque raccordement composé d'un conducteur de neutre, une *borne pour câblage externe* correspondante doit être prévue à proximité des bornes de conducteur de phase associées.

Les dispositifs de raccordement du *conducteur de mise à la terre de protection* doivent satisfaire à 4.4.4.3.2.

4.11.11.4 Espace de courbure des câbles de 10 mm^2 et plus

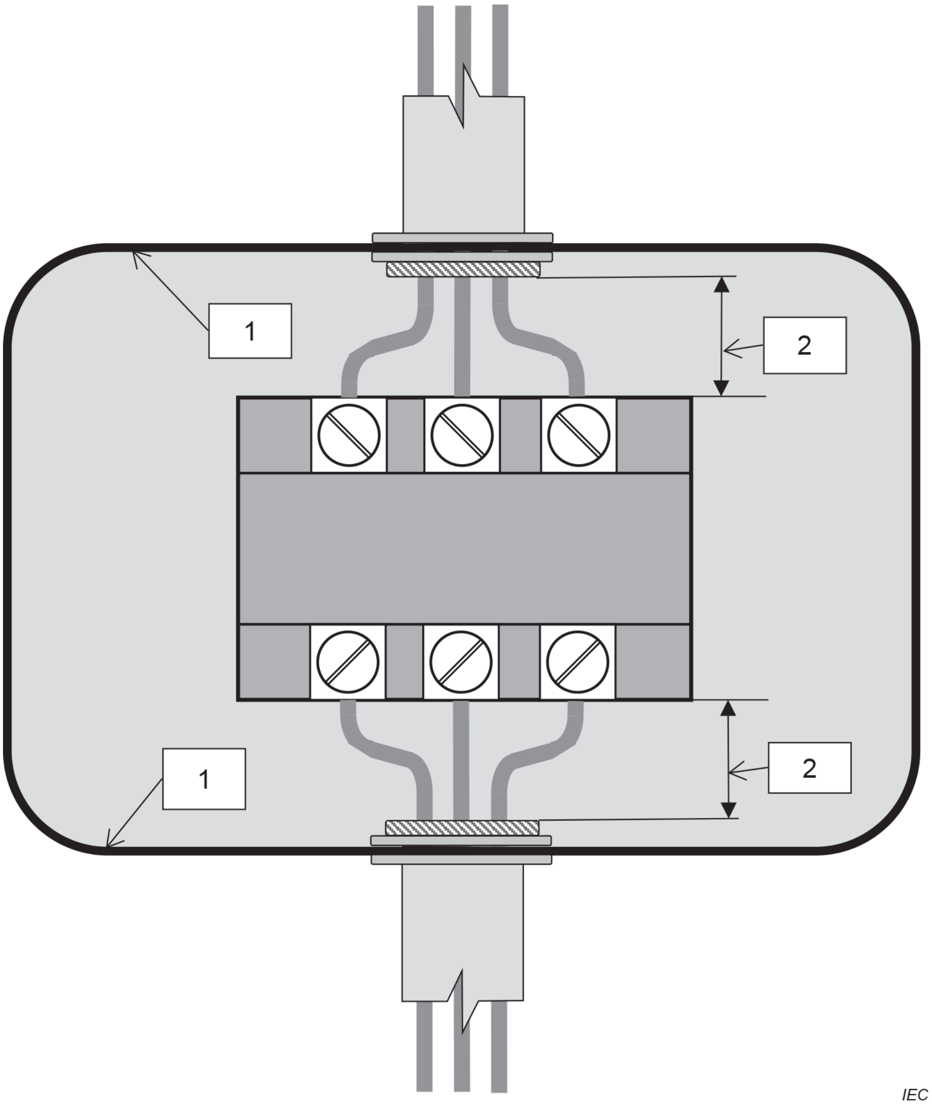
Pour les *BDM/CDM/PDS basse tension*, la distance entre une *borne pour câblage externe* de raccordement au *réseau* ou à l'*alimentation non raccordée directement au réseau*, ou entre les parties principales du *PDS* (par exemple moteur, transformateur, *BDM/CDM*) et l'obstacle vers lequel est dirigé le fil partant de la borne doit être au moins celle spécifiée dans le Tableau 21.

Les *BDM/CDM/PDS* conçus uniquement pour une application particulière avec des exigences d'*installation* uniques doivent satisfaire aux exigences d'espace de courbure correspondant à cette application.

Tableau 21 – Espace de courbure des fils des bornes à l'*enveloppe*

Dimension de fil mm²	Espace de courbure minimal, borne à *enveloppe* mm		
	Nombre de fils par ensemble de bornes		
	1	2	3
10 à 16	40	-	-
25	50	-	-
35	65	-	-
50	125	125	180
70	150	150	190
95	180	180	205
120	205	205	230
150	255	255	280
185	305	305	330
240	305	305	380
300	355	405	455
350	355	405	510
400	455	485	560
450	455	485	610

La Figure 11 présente l'évaluation de l'espace de courbure des fils.



Légende

1 *enveloppe*

2 espace de courbure des fils

Figure 11 – Espace de courbure des fils

Pour les *BDM/CDM/PDS haute tension*, l'espace de courbure des fils minimal pour les conducteurs d'interconnexion entre les parties du *PDS* ou au *réseau* doit être

- 8 fois le diamètre total pour les conducteurs non blindés, ou
- 12 fois le diamètre total pour les conducteurs blindés ou recouverts de plomb.

4.11.12 Dispositions en matière de connexion du blindage du fil ou du câble blindé

Si des dispositions en matière de blindage du fil ou de câble blindé sont fournies, leur construction doit satisfaire à 4.4.4.3.2, 4.11.3, 4.11.4, 4.11.11.1 et 4.12.6.

NOTE Un fil blindé peut s'avérer nécessaire pour satisfaire aux exigences de CEM de l'IEC 61800-3 et aux exigences de sécurité fonctionnelle de l'IEC 61800-5-2.

4.12 Exigences mécaniques pour les *enveloppes*

4.12.1 Généralités

Les exigences du 4.12 viennent en complément des exigences relatives aux enveloppes données dans les autres paragraphes portant sur des dangers particuliers (dangers de chocs électriques du 4.4, dangers dus à l'énergie électrique du 4.5 et dangers d'incendie du 4.6.

Les *enveloppes* doivent être adaptées à une utilisation dans leur environnement prévu. Le fabricant doit spécifier l'environnement prévu (voir 6.3.3) et le degré IP de l'*enveloppe* (voir 5.2.2.3 pour les essais).

Les *BDM/CDM/PDS* doivent présenter une résistance mécanique adaptée et doivent être construits de sorte qu'aucun danger ne se produise dans le cadre de leur manipulation, comme cela peut être prévu.

Les essais de résistance mécanique ne sont pas exigés sur une barrière interne ou une structure similaire, à condition qu'elle satisfasse aux exigences du 4.6.4.1, si l'*enveloppe* assure une protection mécanique.

Une *enveloppe* doit être suffisamment complète pour contenir ou détourner des parties qui, en cas de défaillance ou pour d'autres raisons, peuvent se desserrer, se séparer ou être éjectées d'une partie mobile.

Pour le *PDS intégré,* l'enveloppe des *BDM/CDM* doit satisfaire aux exigences ci-dessus. L'*enveloppe* du moteur doit satisfaire aux exigences des parties appropriées de la série IEC 60034.

Si la ventilation est assurée par air forcé par au moins un ventilateur installé à l'intérieur de l'*enveloppe*, l'air d'échappement ne doit pas souffler directement dans la zone occupée par l'opérateur. Cette zone mesure 0,75 m de largeur (horizontal) centrée sur une commande, un écran ou une poignée de déconnexion de l'opérateur sur l'ensemble de la hauteur (verticale) de l'*enveloppe* pour les *BDM/CDM/PDS* montés au mur ou jusqu'à 2 m au-dessus du sol pour les *BDM/CDM/PDS* posés au sol.

La conformité doit être vérifiée par les essais correspondants de 5.2.2.3 à 5.2.2.6, comme cela est spécifié.

Si l'enveloppe satisfait aux exigences d'épaisseur applicables du 4.12.3 ou du 4.12.4, l'essai du 5.2.2.4.2 peut être ignoré.

Pour le *PDS intégré*, la combinaison du moteur et des *BDM/CDM* doit être soumise à l'essai en fonction de leur environnement prévu. Pour les ventilateurs externes et les orifices de vidange du moteur, les exigences de l'IEC 60034-5:2020 s'appliquent.

Pour les *BDM/CDM* de *type ouvert*, les essais de 5.2.2.2 à 5.2.2.6 ne sont pas exigés.

4.12.2 Poignées et commandes manuelles

Les poignées, boutons, manettes, leviers et éléments similaires doivent être fixés en toute sécurité, de sorte qu'ils ne se desserrent pas en utilisation normale si cela peut provoquer u danger. Les produits d'étanchéité et éléments analogues autres que les résines autodurcissantes ne doivent pas être les seuls moyens utilisés pour éviter le desserrage. Si des poignées, boutons et éléments analogues sont utilisés pour indiquer la position des commutateurs ou *composants* similaires, il ne doit pas être possible de les fixer dans une position incorrecte si cela peut engendrer un danger.

La conformité doit être vérifiée par l'*inspection visuelle* du 5.2.1, et, selon le cas, par les essais du 5.2.2.6.

4.12.3 *Enveloppe* en métal coulé

L'épaisseur des métaux coulés sous pression, sauf dans le cas des trous taraudés pour conduit qui requiert une épaisseur minimale de 6,4 mm

- ne doit pas être inférieure à 2,0 mm pour une surface supérieure à 155 cm2 ou dont l'une des dimensions est supérieure à 150 mm,
- ne doit pas être inférieure à 1,2 mm pour une surface inférieure ou égale à 155 cm2 et dont aucune dimension n'est supérieure à 150 mm.

La surface soumise à évaluation peut être délimitée par des nervures de renforcement qui subdivisent une plus grande surface.

L'épaisseur de la fonte malléable ou de l'aluminium, du laiton, du bronze ou du zinc coulés en coquille, sauf dans le cas des trous taraudés pour conduit qui requiert une épaisseur minimale de 6,4 mm, doit être

- d'au moins 2,4 mm pour une surface plus grande que 155 cm^2 ou dont l'une des dimensions est plus grande que 150 mm,
- d'au moins 1,5 mm pour une surface inférieure ou égale à 155 cm^2 et dont aucune dimension n'est plus grande que 150 mm.

L'épaisseur minimale d'une *enveloppe* en métal coulé dans du sable doit être de 3,0 mm, sauf à l'emplacement des trous taraudés pour conduit, qui requiert une épaisseur minimale de 6,4 mm.

4.12.4 *Enveloppe* en tôle

L'épaisseur d'une enveloppe en tôle aux points où un système de câblage doit être raccordé (conduit, réceptacles, etc.) ne doit pas être inférieure à

a) 0,8 mm pour l'acier nu,
b) 0,9 mm pour de l'acier zingué, et
c) 1,2 mm pour des métaux non ferreux.

L'épaisseur de l'*enveloppe* aux points autres que ceux où doit être raccordé le *système* de câblage ne doit pas être inférieure à celle spécifiée dans le Tableau 22 ou dans le Tableau 23.

En ce qui concerne le Tableau 22 ou le Tableau 23, un châssis support est une structure de tôle à profil angulaire, en U ou replié, et dont l'une des dimensions est égale à au moins l'un des encombrements extérieurs de la surface de l'*enveloppe* ainsi que la rigidité en torsion suffisante pour résister aux moments de flexion exercés par la surface de l'*enveloppe*, lorsqu'elle est soumise à une flexion. Une structure dont la rigidité est celle d'une structure avec un châssis comportant des angles ou des profilés en U dispose d'un renfort équivalent.

Les constructions ne comportant pas de châssis support sont les suivantes

a) les tôles à brides et bords profilés uniques – bords préformés,
b) les tôles ondulées ou nervurées,
c) les surfaces d'*enveloppes* non fermement fixées à un châssis, par exemple à l'aide d'attaches à ressort, et
d) les surfaces d'*enveloppes* dont l'un des bords ne repose pas sur le châssis.

Voir la Figure 12 pour les surfaces d'*enveloppes* reposant et ne reposant pas sur le châssis.

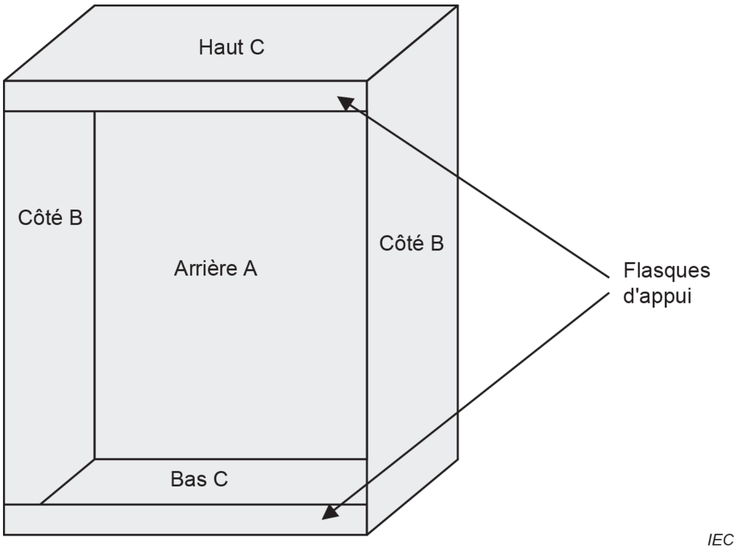


Figure 12 – Surfaces d'enveloppes reposant et ne reposant pas sur le châssis

Chaque surface d'enveloppe est évaluée individuellement en fonction de leur longueur et de leur largeur. Pour chaque ensemble de dimensions de surface, A, B ou C, la largeur est la plus petite dimension quelle que soit son orientation par rapport aux autres surfaces. Le Tableau 22 et le Tableau 23, contiennent deux ensembles de dimensions correspondant à une seule exigence en matière d'épaisseur de métal, et le mode opératoire applicable permettant de déterminer l'épaisseur de métal minimale de chaque surface est décrit ci-après.

Pour une surface reposant sur le châssis, l'ensemble des dimensions du tableau, y compris les longueurs "non limitées" peuvent être appliquées. La surface arrière "A" et les surfaces supérieure et inférieure "C" reposent sur des surfaces voisines de l'*enveloppe* ou sur une bride de 12,7 mm (1/2 pouce) de largeur. Pour déterminer l'épaisseur de métal exigée pour les surfaces soutenues, la largeur doit être mesurée et comparée à la valeur indiquée dans la colonne "Largeur maximale" du tableau, qui est supérieure ou égale à la largeur mesurée. Si la longueur correspondante indiquée dans la colonne "Longueur maximale" est "non limitée", l'épaisseur minimale indiquée dans la colonne la plus à droite doit être utilisée. Si la longueur correspondante de la colonne "Longueur maximale" est une valeur numérique et que la longueur mesurée du côté ne dépasse pas cette valeur, l'épaisseur minimale de la colonne la plus à droite doit être utilisée. Si la longueur mesurée du côté dépasse la valeur numérique, la ligne suivante du Tableau 22 et du Tableau 23 doit être utilisée.

Pour une surface non soutenue, seules les dimensions indiquées dans le tableau qui incluent une exigence de longueur particulière sont appliquées. Les dimensions avec une longueur "non limitée" ne s'appliquent pas. Le bord avant des surfaces "B" de gauche et de droite ne repose pas sur une surface voisine ni n'est soutenu par une bride. Pour déterminer l'épaisseur de métal exigée pour les surfaces non soutenues, la longueur doit être mesurée et comparée à la valeur indiquée dans la colonne "Longueur maximale" du tableau, qui n'est pas inférieure à la longueur mesurée, en ignorant les entrées "non limitées". Si la largeur correspondante indiquée dans la colonne "Largeur maximale" n'est pas inférieure à la largeur mesurée, l'épaisseur minimale indiquée dans la colonne la plus à droite doit être utilisée. Si la largeur mesurée de la surface dépasse la valeur indiquée dans la colonne "Largeur maximale", la ligne suivante du Tableau 22 et du Tableau 23 doit être utilisée.

Tableau 22 – Épaisseur des tôles d'*enveloppes* électriques: acier au carbone ou acier inoxydable

Sans châssis support [a]		Avec châssis support [a]		Épaisseur minimale
Largeur maximale mm [b]	Longueur maximale mm [c]	Largeur maximale mm [b]	Longueur maximale mm [c]	mm
100 120	Non limitée 150	160 170	Non limitée 210	0,6 [d]
150 180	Non limitée 220	240 250	Non limitée 320	0,75 [d]
200 230	Non limitée 290	310 330	Non limitée 410	0,9
320 350	Non limitée 460	500 530	Non limitée 640	1,2
460 510	Non limitée 640	690 740	Non limitée 910	1,4
560 640	Non limitée 790	840 890	Non limitée 1 090	1,5
640 740	Non limitée 910	990 1 040	Non limitée 1 300	1,8
840 970	Non limitée 1 200	1 300 1 370	Non limitée 1 680	2,0
1 070 1 200	Non limitée 1 500	1 630 1 730	Non limitée 2 130	2,5
1 320 1 520	Non limitée 1 880	2 030 2 130	Non limitée 2 620	2,8
1 600 1 850	Non limitée 2 290	2 460 2 620	Non limitée 3 230	3,0

[a] Voir 4.12.4.

[b] La largeur représente la plus petite cote d'une pièce rectangulaire en tôle faisant partie d'une *enveloppe*. Les surfaces voisines d'une *enveloppe* peuvent avoir des supports communs et n'être constituées que d'une seule feuille de tôle.

[c] "Non limitée" ne s'applique que si la surface possède un bord tombé d'au moins 12,7 mm ou lorsqu'elle est fixée aux surfaces voisines qui ne sont normalement pas démontées en cours d'utilisation.

[d] L'épaisseur de la tôle d'une *enveloppe* destinée à un usage en extérieur ne doit pas être inférieure à 0,86 mm.

Tableau 23 – Épaisseur des tôles d'*enveloppes* électriques: aluminium, cuivre ou laiton

Sans châssis support [a]		Avec châssis support [a]		Épaisseur minimale
Largeur maximale, mm [b]	Longueur maximale, mm [c]	Largeur maximale, mm [b]	Longueur maximale, mm [c]	mm
75 90	Non limitée 100	180 220	Non limitée 240	0,6 [d]
100 125	Non limitée 150	250 270	Non limitée 340	0,75
150 165	Non limitée 200	360 380	Non limitée 460	0,9
200 240	Non limitée 300	480 530	Non limitée 640	1,2
300 350	Non limitée 400	710 760	Non limitée 950	1,5
450 510	Non limitée 640	1 100 1 150	Non limitée 1 400	2,0
640 740	Non limitée 1 000	1 500 1 600	Non limitée 2 000	2,4
940 1 100	Non limitée 1 350	2 200 2 400	Non limitée 2 900	3,0
1 300 1 500	Non limitée 1 900	3 100 3 300	Non limitée 4 100	3,9

[a] Voir 4.12.4.

[b] La largeur représente la plus petite cote d'une pièce rectangulaire en tôle faisant partie d'une *enveloppe*. Les surfaces voisines d'une *enveloppe* peuvent avoir des supports communs et n'être constituées que d'une seule feuille de tôle.

[c] "Non limitée" ne s'applique que si la surface possède un bord tombé d'au moins 12,7 mm ou lorsqu'elle est fixée aux surfaces voisines qui ne sont normalement pas démontées en cours d'utilisation.

[d] L'épaisseur des parois en aluminium, cuivre ou laiton d'une *enveloppe* destinée à un usage en extérieur ne doit pas être inférieure à 0,74 mm.

4.12.5 Stabilité des BDM/CDM/*PDS* posés au sol

Dans les conditions normales de fonctionnement, le *BDM/CDM/PDS* ne doit pas devenir physiquement instable au point de présenter un danger pour un opérateur ou une personne de service, même lorsqu'il est incliné.

Des mesures ou des informations visant à prévenir ces types de dangers doivent être fournies dans les instructions d'installation.

Les exigences du 4.12.5 ne s’appliquent pas si les instructions d'installation spécifient que le *BDM/CDM/PDS* doit être fixé à la structure du bâtiment avant son utilisation.

Pour le marquage, voir 6.4.6.

4.12.6 Support d'attache de câbles

Le câblage du *PDS*, y compris les connexions *réseau* et les cordons ou câbles internes, doit être protégé contre déformations, y compris les torsions lorsqu'il est connecté à l'intérieur du *BDM/CDM/PDS*, et son *isolation* doit être protégée contre l'abrasion (voir 4.11.4). Le *conducteur de mise à la terre de protection*, le cas échéant, doit être le dernier élément à prendre la déformation si le câblage glisse dans son support d'attache.

Les supports d'attache doivent satisfaire aux exigences suivantes:

a) le câblage ne doit pas être serré par une vis qui appuie directement sur le câblage;
b) les nœuds dans le câblage ne doivent pas être utilisés;
c) il ne doit pas être possible de pousser le cordon de câblage dans l'équipement au point de pouvoir provoquer un danger;
d) la défaillance de l'*isolation* de câblage du cordon dans le support d'attache de câbles composé de parties métalliques ne doit pas transformer les *parties accessibles* conductrices en *parties actives dangereuses*;
e) le support d'attache de câbles fait l'objet d'un essai de relâchement des contraintes en appliquant le couple et la durée indiqués dans le Tableau 27 aussi proche que possible de l'extrémité externe du support d'attache ou de la traversée;
f) les bords des étriers et guides fils, métalliques ou non, doivent être lisses et arrondis afin d'éviter la défaillance de l'isolation;
g) il ne doit pas être possible de desserrer le support d'attache de câbles sans utiliser d'outil;
h) le support d'attache de câbles doit être conçu de manière à ce que le remplacement du câblage ne présente aucun danger, et la manière dont la déformation est allégée doit être claire.

Les presse-étoupes ne doivent pas servir de support d'attache, sauf si cela est spécifié par le fabricant du presse-étoupe.

La conformité est démontrée par l'*inspection visuelle* du 5.2.1 et par l'essai de relâchement des contraintes du 5.2.2.7.

4.12.7 Détente des contraintes d'une *enveloppe* polymère

Les *enveloppes* en matériau thermoplastique moulé ou profilé doivent être construites de sorte que le rétrécissement ou la déformation du matériau en raison de la détente des contraintes internes provoquées par la manœuvre de moulage ou de profilage n'exposent pas les parties dangereuses ni ne réduisent les *lignes de fuite* ou les *distances d'isolement* conformément à 4.4.7.4 and 4.4.7.5 à des valeurs inférieures aux valeurs minimales.

La conformité doit être vérifiée selon 5.2.2.4.5.

4.12.8 Condensation interne ou accumulation d'eau

Dans les zones où la condensation interne ou l'accumulation d'eau (voir 4.4.7.1.3) est prévue,

- les *distances d'isolement* et les *lignes de fuite* du Tableau 8 et du Tableau 10 doivent être évaluées pour un environnement à degré de pollution au moins égal à 3 (voir le Tableau 5), et
- une disposition doit être prise pour évacuer l'eau.

La conformité est vérifiée par l'*inspection visuelle* du 5.2.1 selon 5.2.2.3.4.

4.12.9 Résistance aux ultraviolets (UV) d'une *enveloppe* polymère à usage extérieur

Les parties polymères d'une *enveloppe* à usage extérieur soumise aux UV doivent être suffisamment résistantes à la dégradation par le rayonnement ultraviolet.

La conformité est vérifiée par

- *une inspection visuelle selon 5.2.1 de la construction et des données disponibles concernant les caractéristiques de résistance aux ultraviolets du matériau de l'enveloppe et du revêtement de protection associé, ou*
- *un essai selon 5.2.5.7.*

Pour le marquage, voir 6.3.3.

4.13 *Composants*

4.13.1 Généralités sur les *composants*

Outre les exigences relatives aux *composants* dans les articles individuels du présent document, les *composants* doivent satisfaire aux paragraphes 4.13.1 à 4.13.6.

Les *composants* identifiés en 4.2, qui sont essentiels pour la sécurité, doivent être utilisés dans les limites de leurs caractéristiques assignées spécifiées.

De plus, ces *composants* doivent

- satisfaire aux exigences du 4.4 en ce qui concerne le danger de chocs électriques,
- satisfaire aux exigences du 4.4.7.1.8 en ce qui concerne les caractéristiques assignées électriques pour la coordination de l'isolation,
- satisfaire aux exigences du 4.5 en ce qui concerne les dangers dus à l'énergie,
- satisfaire aux exigences du 4.6 en ce qui concerne les dangers thermiques et d'incendie,
- satisfaire aux exigences du 4.7 en ce qui concerne les dangers mécaniques,
- satisfaire aux exigences du 4.9 en ce qui concerne les conditions environnementales, et
- satisfaire à leur norme de *composant* correspondante comme cela est spécifié en 1) ou 2).

Les normes de *composants* pertinentes sont considérées comme étant

1) soit la norme de *composant* correspondante,
2) soit, en l'absence de norme de *composant* pertinente, une norme de sécurité de *composant* non IEC pertinente, publiée par une organisation reconnue de développement de normes nationales, internationales ou de l'industrie.

En l'absence de norme de *composant* pertinente, le *composant* doit être soumis aux essais applicables du présent document, comme partie intégrante du *BDM/CDM/PDS* ou individuellement, la condition retenue étant celle qui génère la condition la plus sévère. Toutefois, le *composant* ne doit pas être soumis à l'essai et qualifié en dehors des caractéristiques assignées spécifiées par le fabricant du *composant*.

NOTE 1 Des exemples incluent, entre autres, ce qui suit: les disjoncteurs, les fusibles, les contacteurs, les *composants* assurant une *double isolation* ou une *isolation renforcée* par conception, les soupapes de sécurité, les SPD (MOV, etc.), les résistances utilisées comme *impédance de protection*, etc.

NOTE 2 L'essai de conformité applicable avec une norme de *composant* est en général réalisé séparément.

NOTE 3 La Bibliographie donne une liste informative des normes de *composants* pertinentes. D'autres normes peuvent être utilisées.

4.13.2 *Composants* représentant un danger d'incendie

Les *composants* qui peuvent éventuellement générer un danger d'incendie dans des *conditions anormales de fonctionnement* ou dans des *conditions de premier défaut* ou doivent satisfaire aux exigences du 4.6.3.

4.13.3 *Composants* faisant partie intégrante d'une enveloppe

Les *composants* assurant la protection contre l'accès aux *parties actives dangereuses* dans le cadre de l'*enveloppe* doivent satisfaire aux exigences du 4.4.3.3.

Les *composants* faisant partie d'une *enveloppe ignifuge* selon 4.6.4.2 doivent satisfaire aux exigences du 4.6.4.3, du 4.6.4.4 et du 4.6.5.

4.13.4 *Composants* représentant un danger mécanique

Les *composants* qui peuvent éventuellement générer un danger mécanique dans des conditions normales de fonctionnement, dans des *conditions anormales de fonctionnement* et dans des *conditions de premier défaut* ou doivent satisfaire aux exigences spécifiées en 4.7.

4.13.5 Composants bobinés

L'*isolation* des fils au moyen d'émail ou de vernis ne doit pas être employée pour une *isolation principale*, une *isolation supplémentaire*, une *double isolation* ou une *isolation renforcée*.

Les *composants* bobinés doivent satisfaire aux exigences du 4.4.7.8.1, du 4.4.7.8.3 (selon le cas) et du 4.4.7.10.

Un fil de bobinage isolé dont l'*isolation* peut être utilisée pour assurer l'*isolation principale*, l'*isolation supplémentaire*, la *double isolation* ou l'*isolation renforcée* dans les *composants* bobinés doit satisfaire aux exigences de l'IEC 61558-1:2017, 19.12.3, selon le cas.

Si le *composant* possède une *isolation renforcée* ou une *double isolation*, l'essai de tension alternative ou continue du 5.2.3.4 doit être effectué dans le cadre d'un *essai individuel de série* avec les valeurs correspondant à la *protection principale*.

4.13.6 Dispositifs de protection

Les *composants* agissant comme un dispositif de protection pour la conformité aux essais du 5.2.4 doit satisfaire à 4.13.1.

4.14 Protection contre les champs électromagnétiques

Pour protéger les personnes contre les champs électromagnétiques, l'exposition doit être limitée soit par le *BDM/CDM/PDS* lui-même soit par des mesures externes.

Pour plus d'informations, voir l'Annex P.

Pour la conformité, voir 5.2.8.

5 Exigences d’essais

5.1 Généralités

5.1.1 Objectifs et classification des essais

Les essais tels que définis dans le présent Article 5 sont nécessaires pour démontrer que le *BDM/CDM/PDS* satisfait totalement aux exigences du présent document pour l'usage prévu, les conditions normales de fonctionnement, les *conditions anormales de fonctionnement* et les *conditions de premier défaut*. Les essais peuvent être ignorés si les exigences correspondantes de l'Article 4 le permettent.

L’Article 5 décrit les procédures à adopter pour les essais propres au *PDS*. Les essais sont classés comme suit

- *essais de type*,
- *essais individuels de série*, et
- *essais sur prélèvement*.

AVERTISSEMENT – Ces essais peuvent créer des situations à risques. Des précautions sont nécessaires pour éviter toute blessure.

5.1.2 Sélection des échantillons pour les essais

Lors des essais d’une gamme ou d’une série de produits similaires, il peut ne pas être nécessaire de soumettre à l'essai tous les modèles, y compris les *accessoires*, de la gamme. Chaque essai doit être réalisé sur un ou plusieurs modèles possédant des caractéristiques mécaniques et électriques qui représentent de façon adéquate toute la gamme pour cet essai particulier.

Pour des instructions plus détaillées sur la sélection de l'échantillon, voir 5.1.5.2.

5.1.3 Séquence d’essais

En général, il n’y a aucune exigence pour que les essais soient effectués dans un ordre donné et il n’est pas non plus nécessaire qu’ils soient tous réalisés sur le même échantillon de *BDM/CDM/PDS*. Toutefois, les critères d'acceptation de certains essais exigent qu’ils soient suivis par un ou plusieurs essais supplémentaires.

5.1.4 Conditions de mise à la terre

Les exigences d’essais doivent être déterminées en utilisant le *système* de mise à la terre le plus défavorable (avec le maximum de contraintes) du 4.4.7.1.5 et spécifié par le fabricant.

Voir également 4.4.7.1.7 et 6.2.1.

5.1.5 Conditions générales d'essai

5.1.5.1 Application des essais

Le *BDM/CDM/PDS* doit être en mesure de fonctionner dès la fin de l'essai, sauf si le paragraphe spécifique relatif à l'essai donne des informations supplémentaires.

5.1.5.2 Sélection des échantillons pour les essais

Sauf spécification contraire, l'échantillon en essai doit être représentatif du *BDM/CDM/PDS* que l'utilisateur reçoit.

Au lieu de réaliser les essais sur l'ensemble du *BDM/CDM/PDS*, les essais peuvent être réalisés séparément sur des circuits, des *composants* ou des sous-ensembles en dehors du *BDM/CDM/PDS*, à condition que l'*inspection visuelle* du 5.2.1 du *BDM/CDM/PDS* et des dispositions du circuit indique que les résultats des essais sont représentatifs des résultats des essais réalisés sur le *BDM/CDM/PDS* assemblé. Si ce type d'essais indique une probabilité de non-conformité dans l'ensemble du *BDM/CDM/PDS*, l'essai doit être répété dans le *BDM/CDM/PDS*.

Si, dans le présent document, la conformité des matériaux, des *composants* ou des sous-ensembles est vérifiée par l'*inspection visuelle* du 5.2.1 ou par des essais de propriétés, il est admis de confirmer la conformité en consultant les données pertinentes ou les précédents résultats d'essai disponibles au lieu de réaliser les *essais de type* spécifiés. Voir également 4.1.

EXEMPLE Essais réalisés sur des *enveloppes* composées du même matériau, mais qui sont de dimensions différentes, peuvent être représentés par une seule *enveloppe*, alors que les essais réalisés sur des *composants* de puissance dont les caractéristiques assignées sont différentes ne peuvent pas être représentés par des essais réalisés sur un modèle particulier.

5.1.5.3 Paramètres de fonctionnement pour les essais

Sauf indication contraire dans un article spécifique relatif aux essais, les conditions d'essai du Tableau 24 s'appliquent.

Tableau 24 – Conditions environnementales pour les essais

Température °C	**Humidité relative** %	**Pression atmosphérique** kPa
15 à 35	25 à 75	86 à 106
Source: IEC 60068-1:2013, Tableau 2. NOTE Si les conditions ci-dessus ne peuvent pas être obtenues, les essais peuvent être réalisés dans la plage assignée des conditions climatiques du *BDM/CDM/PDS*.		

Sauf si les conditions d'essai spécifiques sont indiquées ailleurs dans le présent document et qu'il est clair que l'impact sur les résultats de l'essai est significatif, les essais doivent être réalisés dans la combinaison la plus défavorable, dans les limites des spécifications de fonctionnement du fabricant des paramètres suivants:

- tension d'entrée assignée;
- fréquence d'entrée assignée; ou courant continu;
- plage de températures de fonctionnement en tenant compte de l'allègement de régime et des caractéristiques de commande de refroidissement;
- emplacement physique du *BDM/CDM/PDS* et position des parties *déplaçables*;
- mode de fonctionnement;
- conditions de charge;
- réglage des thermostats, des dispositifs de régulation ou des commandes similaires dans la *zone d'accès pour la maintenance*, qui sont
  – réglables sans l'aide d'un outil ou d'une clé, ou
  – réglables à l'aide de moyens tels qu'une clé ou un outil, volontairement fournis par l'opérateur.

Les *BDM/CDM/PDS* prévus pour des alimentations en courant alternatif dans la plage comprise entre 50 Hz et 60 Hz doivent être soumis à l'essai à une fréquence dans la plage comprise entre 48 Hz et 62 Hz.

5.1.5.4 Montage

Chaque *BDM/CDM/PDS* doit être monté comme décrit dans les instructions d'installation du fabricant. Si les instructions d'installation spécifient plusieurs positions de montage, une analyse doit être réalisée pour déterminer la ou les positions de montage qui vont donner la condition d'essai la plus défavorable.

5.1.6 Conformité

La conformité au présent document doit être vérifiée en effectuant les essais appropriés spécifiés dans l'Article 5.

La conformité ne peut être affirmée que lorsque tous les essais appropriés donnent des résultats satisfaisants.

La conformité aux exigences de construction et aux informations devant être fournies par le fabricant doit être vérifiée par un examen, une *inspection visuelle* du 5.2.1, et/ou des mesurages appropriés.

Dès que des modifications de conception ou de *composant* ont un impact potentiel sur la conformité, un nouvel *essai de type* ou une nouvelle évaluation technique (par des calculs, par exemple) doit être effectué(e) pour confirmer la conformité.

5.1.7 Vue d'ensemble des essais

Le Tableau 25 donne une vue d'ensemble de l'*essai de type*, de l'*essai individuel de série* et de l'*essai sur prélèvement* des *composants*/dispositifs électroniques et des *BDM/CDM/PDS*.

Tableau 25 – Vue d'ensemble des essais

Essai	*De type*	*Individuel de série*	*Sur prélèvement*	Exigence(s)	Spécification
Vérification générale					
Inspection visuelle	X	X	X		5.2.1
Essais mécaniques					5.2.2
Essai de *distances d'isolement* et de *lignes de fuite*	X			4.4.7.4, 4.4.7.5	5.2.2.1
Essai de non-accessibilité	X			4.4.3.3, 4.7.5	5.2.2.2
Essai d'intégrité de l'enveloppe (classification IP)	X			4.12.1	5.2.2.3
Essai à l'eau atomisée	X			4.12.1	5.2.2.3.2
Essai IEC 60529 d'*enveloppe* de catégorie 1 ou 2 pour IP5X	X			-	5.2.2.3.3
Essai d'accumulation d'eau	X			4.12.8	5.2.2.3.4
Essai d'intégrité de l'*enveloppe*	X			4.12.1	5.2.2.4
Essai de flexion	X			4.4.7.4.5, 4.12.1	5.2.2.4.2
Essai de force constante, 30 N	X			4.4.7.4.5, 4.12.1	5.2.2.4.2.2
Essai de force constante, 250 N	X			4.4.7.4.5, 4.12.1	5.2.2.4.2.3
Essai de choc	X			4.12.1	5.2.2.4.3
Essai de chute	X			4.12.1	5.2.2.4.4

Essai	*De type*	*Individuel de série*	*Sur prélèvement*	Exigence(s)	Spécification
Essai de déformation par réduction des contraintes de moulage	X			4.12.7	5.2.2.4.5
Essai des *BDM/CDM/PDS* fixés au mur ou au plafond	X			4.12.1	5.2.2.5
Essai de fixation des poignées et organes de contrôle manuels	X			4.12.2	5.2.2.6
Essai de relâchement des contraintes	X			4.11.10.2.2, 4.12.6	5.2.2.7
Essai des dispositifs d'isolation et de l'intégrité du verrouillage	X			4.4.10.1, 4.4.10.2.1.1	5.2.2.8
Essai de bruit acoustique	X			4.10.2	5.2.2.9
Essais électriques					
Essai de tension de tenue aux chocs	X		X	4.4.3.2, 4.4.5.4, 4.4.7, 4.4.7.10.1, 4.4.7.10.2, 4.4.7.10.3, 4.4.7.8.3, 5.2.2.1	5.2.3.2
Alternative à l'essai de tension de tenue aux chocs	X		X	-	5.2.3.3
Essai de tension en courant alternatif ou en courant continu	X	X		4.4.3.2, 4.4.5.4, 4.4.7.10.1, 4.4.7.10.2, 4.4.7.10.3, 4.4.7.8.4.3	5.2.3.4
Essai de décharge partielle	X		X	4.4.7.8	5.2.3.5
Essai d'impédance de protection	X	X		4.4.5.4	5.2.3.6
Essai de mesure du courant de contact	X			4.4.4.3.3	5.2.3.7
Essai de décharge du condensateur	X			4.4.9	5.2.3.8
Essai de source de puissance limitée	X			4.5.2, 4.5.3	5.2.3.9
Essai d'échauffement	X			4.6.5	5.2.3.10
Essai de continuité de liaison équipotentielle de protection	X	X		4.4.4.2	5.2.3.11
Essai de continuité de la *liaison équipotentielle de protection*	X	X		4.4.4.2.2	5.2.3.11.2
Essai à l'entrée du circuit	X			6.2.1	5.2.3.12
Essai du matériau pelliculé	X			4.4.7.8.3	5.2.3.13
Procédure d'essai de matériau pelliculé séparable	X			4.4.7.8.3	5.2.3.13.2
Essai au mandrin	X		X	4.4.7.8.3	5.2.3.13.3
Procédure d'essai pour la détermination de la tension de fonctionnement	X			4.4.7.1.2	5.2.3.14
Essai de surveillance du SPD interne	X			4.4.7.2.2	5.2.3.15
Préconditionnement du matériau	X			4.4.7.8.4.2, 4.4.7.8.4.3, 4.4.7.9	5.2.3.16
Essais de *fonctionnement anormal* et de défauts simulés					
Essai de la liaison équipotentielle de protection	X			4.3.1, 4.3.2.2, 4.4.4.2	5.2.4.4

Essai	*De type*	*Individuel de série*	*Sur prélèvement*	Exigence(s)	Spécification
Essai de court-circuit en sortie	X			4.3.2.2, 4.3.2.3, 4.3.3	5.2.4.5
Essai de court-circuit entre les bornes de phase de l'*accès* de puissance de sortie	X			4.3.1	5.2.4.5.2
Essai de court-circuit entre les bornes de phase des *accès* de puissance de sortie et la terre	X			4.3.1	5.2.4.5.3
Essai de protection électronique contre les surcharges du moteur	X			4.3.5	5.2.4.6.4
Essai de déclenchement de la rétention de mémoire thermique du moteur électronique	X			4.3.5	5.2.4.6.5
Essai de perte de puissance de la rétention de mémoire thermique du moteur électronique	X			4.3.5	5.2.4.6.6
Essai de sensibilité thermique à la vitesse du moteur électronique	X			4.3.5	5.2.4.6.7
Essai d'évaluation de la fonctionnalité du circuit	X	X	X	5.2.4.5, 5.2.4.6,	5.2.4.7
Essai de limitation de courant	X			4.3.6	5.2.4.8
Essai de surcharge en sortie	X			4.6.1	5.2.4.9
Essai de défaillance de composants	X			4.2, 4.3.2.2	5.2.4.10
Essai de court-circuit de la carte de circuit imprimé	X			4.4.7.7	5.2.4.11
Essai de perte de phase	X			4.2	5.2.4.12
Essais de défaillance du refroidissement	X			4.2, 4.7.4.3.7	5.2.4.13
Essai de moteur de ventilateur inopérant	X			4.2	5.2.4.13.2
Essai de filtre colmaté	X			4.2	5.2.4.13.3
Essai de perte de liquide de refroidissement	X			4.7.4.3.7	5.2.4.13.4
Essai de couverture des ouvertures pour l'air de refroidissement	X			4.2	5.2.4.13.5
Essais de matériaux				4.4.7.8.2, 4.6.4.2	5.2.5
Essai d'allumage d’un arc à forte intensité	X			4.4.7.8.2	5.2.5.2
Essai au fil incandescent	X			4.4.7.8.2	5.2.5.3
Essai d'allumage avec fil chaud	X			4.4.7.8.2	5.2.5.4
Essai d'inflammabilité	X			4.6.4.2	5.2.5.5
Essai de joint scellé	X			4.4.7.9	5.2.5.6
Résistance aux UV	X			4.12.9	5.2.5.7
Essais d’environnement	X			4.9	5.2.6
Procédure de préconditionnement ou de recouvrement pour les essais climatiques	X			4.9	5.2.6.3.1

Essai	*De type*	*Individuel de série*	*Sur prélèvement*	Exigence(s)	Spécification
Essai de chaleur sèche (régime permanent)	X			4.9	5.2.6.3.2
Essai à basse température (régime permanent)	X			4.9	5.2.6.3.3
Essai de chaleur humide (régime permanent)	X			4.9	5.2.6.3.4
Essai de chaleur humide (cyclique)	X			4.9	5.2.6.3.5
Essai de vibration	X			4.9	5.2.6.4
Essai de brouillard salin	X			4.9	5.2.6.5
Essai de poussière	X			4.9	5.2.6.6
Essai de sable	X			4.9	5.2.6.7
Essai de pression hydrostatique	X	X		4.7.4.3.3	5.2.7
Champs électromagnétiques (CEM)	X			4.14	5.2.8

5.2 Spécifications des essais

5.2.1 *Inspections visuelles* (*essai de type, essai individuel de série* et *essai sur prélèvement)*

Des *inspections visuelles* doivent être effectuées

- comme *essais individuels de série*, pour vérifier les éléments tels que l'adéquation de l'étiquetage, des avertissements et d'autres aspects relatifs à la sécurité, et
- pour vérifier
  - les mesures de conception et les fiches techniques comme cela est spécifié dans les paragraphes 4.3 à 4.14,
  - les critères d'acceptation des essais individuels des paragraphes 5.2.2 à 5.2.7, et
  - les exigences pertinentes relatives aux informations et au marquage comme cela est spécifié dans les paragraphes 6.2 à 6.5.

Les *inspections visuelles* de série peuvent faire partie du processus de production ou d'assemblage.

Avant de procéder aux *essais de type*, il doit être vérifié que le *BDM/CDM/PDS* fourni pour l'essai est tel que prévu en ce qui concerne la tension d'alimentation, aux plages d'entrée et de sortie, etc.

5.2.2 Essais mécaniques

5.2.2.1 Essais de *distances d'isolement* et de *lignes de fuite* (*essai de type*)

La conformité à 4.4.7.4 et à 4.4.7.5 des *distances d'isolement* et des *lignes de fuite* doit être vérifiée par mesurage et par l'*inspection visuelle* du 5.2.1. Voir l'Annex D pour des exemples de mesurages.

L'essai de *tension de tenue aux chocs* (voir 5.2.3.2) doit être réalisé aussi proche que possible de la distance à l'étude

- lorsque ce mesurage et l'*inspection visuelle* du 5.2.1 sont impossibles à réaliser, mais que la documentation de construction démontre la conformité à 4.4.7.4 et à 4.4.7.5, ou

- si la *distance d'isolement* est conçue pour les conditions de champ homogènes du 4.4.7.4.4.

5.2.2.2 Essai de non-accessibilité (*essai de type*)

Cet essai vise à démontrer que les *parties actives dangereuses*, par exemple les pales de ventilateur, et les parties mobiles dangereuses sont protégées par des enveloppes ou des barrières conformes à 4.4.3.3 et à 4.7.5.

Cet essai doit être effectué comme un *essai de type* de l'*enveloppe* d'un *BDM/CDM/PDS*, comme cela est spécifié dans l'IEC 60529 pour la classification de l'*enveloppe* dans le cadre d'une protection contre l'accès aux parties dangereuses, sauf pour ce qui suit.

Les doigts d'épreuve de l'IEC 61032:1997 doivent s'appliquer et sont reproduits à l'Annex M.

Essai 1 (Protection contre l'accès avec un doigt, IP2X, IPXXB):

Lorsque le doigt d'essai joint selon la Figure M.2 est inséré dans une ouverture d'une *enveloppe* ou d'une barrière avec une force de 10 N ± 10 % et plié dans n'importe quelle direction,

- Le doigt d'essai ne doit pas entrer en contact avec les parties mobiles dangereuses (voir 4.7.5.2),
- une distance d'isolement adéquate avec les *parties actives dangereuses* doit être maintenue (voir 4.4.3.3.1 et 4.4.3.3.2), et
- le doigt d'essai ne doit pas ponter deux parties entre lesquelles il existe une énergie électrique dangereuse (voir 4.5.1).

Essai 2 (Protection contre l'accès avec un corps étranger, IP2X):

Lorsque le diamètre total de la sphère de 12,5 mm selon la Figure M.4 est inséré dans une ouverture d'une *enveloppe* ou d'une barrière avec une force de 30 N ± 10 %, le calibre d'essai ne doit pas traverser entièrement l'ouverture (voir 4.4.3.3.1).

Essai 3 (Protection contre l'accès avec le dos de la main, IPXXA):

Lorsque le calibre d'essai de 50 mm selon la Figure M.1 est utilisé pour démontrer la protection contre les contacts involontaires lorsque l'*enveloppe* est destinée à être ouverte par des *personnes qualifiées* et que le *BDM/CDM/PDS* est mis sous tension pendant l'installation ou la maintenance,

- le calibre d'essai ne doit pas traverser entièrement l'ouverture (voir 4.4.3.3.2),
- le calibre d'essai ne doit pas entrer en contact avec des parties mobiles dangereuses, et
- une distance d'isolement appropriée aux *parties actives dangereuses* doit être maintenue (voir 4.4.3.3.2).

Essai 4 (Protection contre l'accès aux parties dangereuses avec un outil, IPXXC, surface supérieure):

Lorsque la tige d'essai de 2,5 mm selon la Figure M.3, est insérée dans la surface supérieure d'une *enveloppe* ou d'une barrière selon une direction verticale limitée à ±5 ° avec une force de 3 N ± 10 %, une distance d'isolement appropriée aux *parties actives dangereuses* doit être maintenue (voir 4.4.3.3.5.1).

NOTE Le niveau IPXXC permet au doigt d'épreuve d'entrer dans l'*enveloppe* (semblable à l'exemple pour le niveau IP1XD de l'IEC 60529:1989, Annexe A, référence 8).

Pour la conformité, voir 5.2.2.1 et le Tableau A.1 en ce qui concerne le doigt d'épreuve approprié.

Les calibres d'essai de l'IEC 61032:1997 sont reproduits à l’Annex M.

5.2.2.3 Essai d'intégrité de l'enveloppe (classification IP) (*essai de type*)

5.2.2.3.1 Généralités

Comme cela est exigé en 4.12.1, la classification IP annoncée de l’*enveloppe* doit être vérifiée. Cet essai doit être effectué comme un *essai de type* de l’*enveloppe* d’un *BDM/CDM/PDS*, comme cela est spécifié dans l’IEC 60529 pour la classification de l’*enveloppe*.

Conjointement avec l'IEC 60529:1989, 11.2, les éléments suivants s’appliquent.

a) Un échantillon représentatif doit être soumis à l'essai.
b) L'*enveloppe* doit être montée pour l'essai comme cela est indiqué en 5.1.5.4.
c) L'essai peut être réalisé avec une *enveloppe* vide ou une *enveloppe* ne contenant pas toutes les parties qui composent le produit complet s'il peut être démontré que le fait de retirer ces parties n'a pas d'impact sur les résultats d'essai. Le fabricant doit apporter la preuve que la pénétration d'eau ou de poussière n'enfreint pas les critères d'acceptation de l'essai IP de chiffre caractéristique correspondant.
d) Si une *enveloppe* dont le volume est supérieur à 2 m^3 est composée de nombreux joints identiques (un joint entre au moins deux éléments) avec des modèles de fixation similaires, il est admis de soumettre à l'essai un joint représentatif. Cela inclut les portes, les panneaux, les fentes d'expédition, les panneaux d'accès ou autres structures mécaniques de l'enveloppe représentant un potentiel point de pénétration dont la construction est présente plusieurs fois dans la même enveloppe.
e) Le *BDM/CDM/PDS* doit être soumis à l'essai en prenant en considération les exigences les plus sévères des conditions suivantes:
   – mis sous tension;
   – non mis sous tension;
   – parties mobiles en mouvement;
   – parties mobiles non en mouvement.

Une analyse peut être utilisée pour indiquer que la condition d'essai la plus sévère peut être ignorée si cette condition d'essai n'a aucun impact sur les résultats de l'essai. Une justification technique de la configuration d'essai doit être documentée avec les résultats d'essai.

Il est possible d’utiliser de la peinture ou de la colle dont la couleur change au contact de l'eau (ce qui permet de suivre la voie d'eau) ou d'installer un équipement vidéo à l'intérieur de l'*enveloppe*. D'autres méthodes non mentionnées peuvent être utilisées. La conformité de la dépose de l'équipement relève de la responsabilité du fabricant.

Les méthodes d'essai décrites dans l'IEC 60529:1989, Figure 4 et Figure 5 sont admises lors des essais IPX3 et IPX4 de l'IEC 60529:1989, 14.2.3 et 14.2.4.

L'essai à l'eau atomisée du 5.2.2.3.2 est admis en lieu et place d'un essai de poussière pour les classifications IP5X et IP6X si l'*enveloppe* relève de la catégorie 2 (5.2.2.3.3). Si cet essai est utilisé, il est admis d'adapter le produit à la classification IP5X ou IP6X à la discrétion du fabricant. Une classification IP5X peut être exigée après l'essai à l'eau atomisée si seul le milieu filtrant est de classification IP5X.

Voir 5.2.2.3.2 pour l’essai.

Il n'est pas acceptable de soumettre à l'essai les ouvertures de ventilation avec la méthode de l'essai à l'eau atomisée pour IP5X ou IP6X. Toutefois, le joint d’étanchéité entre l'ouverture de ventilation et le logement peut être soumis à l'essai à l'aide de cette méthode.

L'essai à l'eau atomisée ne peut pas être utilisé pour déterminer la manière dont la poussière s'accumule à l'intérieur de l'*enveloppe*, ce qui peut donner lieu à une condition dangereuse. Les exigences les plus strictes d'IP6X sont donc imposées. Si des filtres sont inclus, une classification IP5X peut être exigée pour le *BDM/CDM/PDS* en fonction de la qualification du filtre. Voir 4.12.1 pour les exigences de classification IP.

5.2.2.3.2 Essai à l'eau atomisée (*essai de type*)

Le joint d'*enveloppe* avec joints doit être soumis à une pulvérisation d'eau atomisée à l'aide d'une buse à deux liquides produisant une forme arrondie de (75 à 100) mm de diamètre lorsque le mesurage est réalisé à 300 mm au maximum de la buse. La pression de l'air doit être réglée sur au moins 200 kPa et le débit à au moins 11,4 l/h.

NOTE 1 L'essai à l'eau atomisée est issu du NEMA 250.

NOTE 2 L'essai à l'eau atomisée peut être utilisé pour soumettre à l'essai toute l'*enveloppe* ou une configuration intégrant un joint d'étanchéité conçue comme un sous-ensemble, le joint d'étanchéité ne pouvant être validé sur le *BDM/CDM/PDS* final.

La buse doit être maintenue à une distance comprise entre (300 et 350) mm du joint d'étanchéité de l'*enveloppe*, et la pulvérisation d'eau doit être orientée une fois vers tous les points de pénétration potentielle de poussière. Le mouvement le long des points d'entrée de poussière doit être réalisé à une vitesse linaire maximale de 0,5 cm/s.

L'essai doit être considéré comme ayant satisfait aux exigences de classification IP5X et IP6X si, à l'issue de l'essai, l'eau n'est pas entrée dans l'*enveloppe*.

Comme cela est indiqué en 5.2.2.3.3, un vide est appliqué pendant cet essai conformément aux exigences relatives aux *enveloppe*s de catégorie 1 de l'IEC 60529 pour les *enveloppe*s IP5X lorsque le cycle de fonctionnement normal du *BDM/CDM/PDS* réduit la pression atmosphérique à l'intérieur de l'*enveloppe* en dessous de celle de l'environnement (effets de cyclage thermique, par exemple).

Pour les *enveloppe*s IP5X, en l'absence de différence de pression par rapport à l'air de l'environnement comme cela est déterminé en 5.2.2.3.3, aucun vide n'est appliqué pour l'essai.

Un vide doit être appliqué pendant l'essai pour toutes les *enveloppe*s IP6X conformément aux exigences relatives aux *enveloppe*s de catégorie 1 selon l'IEC 60529.

5.2.2.3.3 Essai IEC 60529 d'*enveloppe* de catégorie 1 ou 2 pour IP5X (*essai de type*)

Pour déterminer si l'*enveloppe* IP5X appartient à la catégorie 1 ou à la catégorie 2, l'essai suivant doit être réalisé. L'essai est réalisé en mesurant la pression atmosphérique interne de l'*enveloppe* et la pression atmosphérique juste à l'extérieur de l'*enveloppe* avec tous les points de données thermiques exigés à l'intérieur de l'*enveloppe*, dans l'ordre indiqué:

1) en commençant à "l'état DÉSACTIVÉ" avec toutes les parties à la température ambiante;
2) en faisant fonctionner le *BDM/CDM/PDS* à pleine charge tant que la température n'est pas stable;
3) en replaçant le *BDM/CDM/PDS* à "l'état DÉSACTIVÉ" avec toutes les parties à la *température ambiante*.

Pendant l'essai, les trous et ouvertures doivent

- utiliser les filtres minimaux IP5X, ou
- être scellés.

Pendant l'essai, la pression interne de l'*enveloppe* ne doit pas diminuer sous la pression extérieure de 2 kPa à tout moment. Si ce résultat est obtenu, le *BDM/CDM/PDS* relève de la catégorie 2 et aucun vide n'est appliqué pour l'essai.

5.2.2.3.4 Accumulation d’essais d'eau (*essai de type*)

Lorsque cela est exigé en 4.12.8, il doit être prouvé par l'*inspection visuelle* du 5.2.1 que

- la *distance d'isolement* et les *lignes de fuite* selon 4.4.7.4 et 4.4.7.5 sont maintenues entre les *parties actives dangereuse*s et l'eau accumulée, si l'eau est considérée comme étant une partie conductrice (voir le Tableau A.1), et
- l'*enveloppe* intègre un drain ou d'autres moyens de vidanger et d'évacuer l'eau accumulée.

Si la conformité ne peut pas être déterminée de manière concluante par l'*inspection visuelle* du 5.2.1, l'essai de tension en courant alternatif ou en courant continu (*essai de type*) du 5.2.3.4 doit être réalisé.

L'accumulation d'eau dans les zones de l'*enveloppe* qui n'enfreint pas les critères d'acceptation du 5.2.2.3.5 est acceptable.

5.2.2.3.5 Critères d’acceptation

Le paragraphe 5.2.2.3.5 est destiné à être utilisé conjointement avec les critères d'acceptation de l'IEC 60529.

Pour les seconds chiffres caractéristiques 1 à 6 définis dans l'IEC 60529, si de l'eau est entrée dans l'*enveloppe*, elle ne doit pas

a) être en quantité suffisante pour gêner le bon fonctionnement du *BDM/CDM/PDS* ou compromettre la sécurité,
b) se déposer sur les parties de l'*isolation* pouvant donner lieu à un suivi le long des *lignes de fuite*,
c) atteindre les *parties actives*,
d) s'accumuler à proximité de l'extrémité de câble ou pénétrer dans le câble, le cas échéant,
e) s'accumuler à proximité d'une entrée ou sortie de câble, et
f) réduire les *distances d'isolement* et les *lignes de fuite* exigées en 4.4.7.4 et 4.4.7.5 entre les *parties actives dangereuse*s et l'eau accumulée.

5.2.2.4 Essai d’intégrité de l’*enveloppe* (*essai de type*)

5.2.2.4.1 Généralités

Les essais d'intégrité de l’*enveloppe* s'appliquent au *BDM/CDM/PDS*, lequel est également destiné à fonctionner sans *enveloppe* supplémentaire dans des *zones d'accès limité*.

Les essais d'intégrité de l’*enveloppe* doivent être effectués sur le point le plus défavorable de la ou des surfaces accessibles représentatives de l’*enveloppe*.

À l'issue de l'essai d'intégrité de l’*enveloppe*, le *BDM/CDM/PDS* doit satisfaire aux essais électriques du 5.2.3.2 et du 5.2.3.4 et doit être examiné pour confirmer

a) qu'aucune dégradation de *composant* lié à la sécurité des *BDM/CDM/PDS* ne s'est produite,
b) que les *parties actives dangereuses* ne sont pas devenues accessibles (voir 4.4.3.3),
c) que les *enveloppes* ne présentent pas de fissures ou d’ouvertures pouvant entraîner un danger,
d) que les *distances d'isolement* ne sont pas inférieures aux valeurs exigées et que les autres *isolations* ne sont pas endommagées,
e) que les barrières ne sont pas endommagées ou desserrées, et
f) qu'aucune partie mobile pouvant entraîner un danger n’est exposée.

Il n’est pas nécessaire que les *BDM/CDM/PDS* soient opérationnels après les essais, et l’*enveloppe* peut être tellement déformée que sa classification IP originale n'est pas maintenue.

5.2.2.4.2 Essai de flexion (*essai de type*)

5.2.2.4.2.1 Généralités

Lorsque cela est exigé par 4.4.7.4.5 ou 4.12.1, l'essai du 5.2.2.4.2.2 et du 5.2.2.4.2.3 s'applique pour l'*enveloppe* métallique, selon le cas.

L'*enveloppe* doit être fermement fixée contre un support rigide.

Les essais ne s'appliquent pas aux poignées, aux leviers, aux boutons ou aux *capots* transparents ou translucides des dispositifs d'indication ou de mesure, sauf si les *parties actives dangereuses* sont accessibles au moyen d'un doigt d'essai joint selon la Figure M.2, si la poignée, le levier, le bouton ou le *capot* est retiré.

Après les essais du 5.2.2.4.2.2 et du 5.2.2.4.2.3, les *enveloppes* conductrices mises à la terre ou non

- ne doivent pas réduire les *distances d'isolement* (4.4.7.4) et les *lignes de fuite* (4.4.7.5) par rapport aux *parties actives* exigées pour l'*isolation principale*, ou
- doivent résister à l'essai de *tension de tenue aux chocs* du 5.2.3.2 pour l'*isolation principale*.

Les dommages affectant le revêtement, ainsi que les entailles et autres éclats peu importants qui n’altèrent pas la protection contre les chocs électriques ou l’humidité, peuvent être ignorés.

5.2.2.4.2.2 Essai de force constante, 30 N

Les parties d'une enveloppe se trouvant dans des *zones d’accès pour la maintenance* ou des *zones d'accès limité*, qui sont protégées par un *capot* ou une *porte* satisfaisant aux exigences du 5.2.2.4.2.3, sont soumises à une force constante de 30 N ± 3 N pendant 5 s, appliquée au moyen d'une version non jointée droite du doigt d'essai joint selon la Figure M.2, sur la partie sur ou à l'intérieur du *BDM/CDM/PDS*.

5.2.2.4.2.3 Essai de force constante, 250 N

L'*enveloppe* ou les surfaces externes des *enveloppes* sont soumises à une force constante de 250^{+10}_{-0} N, pendant au moins 5 s, appliquée successivement en haut, en bas et sur les côtés de l'*enveloppe* fixée au *BDM/CDM/PDS*, avec l'extrémité d'une tige ayant une face plane en acier de (12,7 x12,7) mm.

Pour les surfaces qui ne sont ni horizontales ni verticales, l'essai doit être réalisé en inclinant le *BDM/CDM/PDS* de manière adaptée, de sorte que la surface soit horizontale ou verticale.

5.2.2.4.3 Essai de choc (*essai de type*)

Les surfaces polymères externes des *enveloppes*, dont la défaillance donne accès aux parties dangereuses, sont soumises à l'essai comme suit.

Un échantillon composé de l'ensemble de l’*enveloppe* ou d’une partie de celle-ci représentant la surface non renforcée la plus large, est supporté dans sa position normale. Une bille en acier lisse solide d'environ 50 mm de diamètre et pesant 500 g ± 25 g initialement au repos est laissée tomber librement sur une distance verticale (H) de 1,3 m (voir la Figure 13) sur l'échantillon. Les surfaces verticales ne sont pas concernées par cet essai.

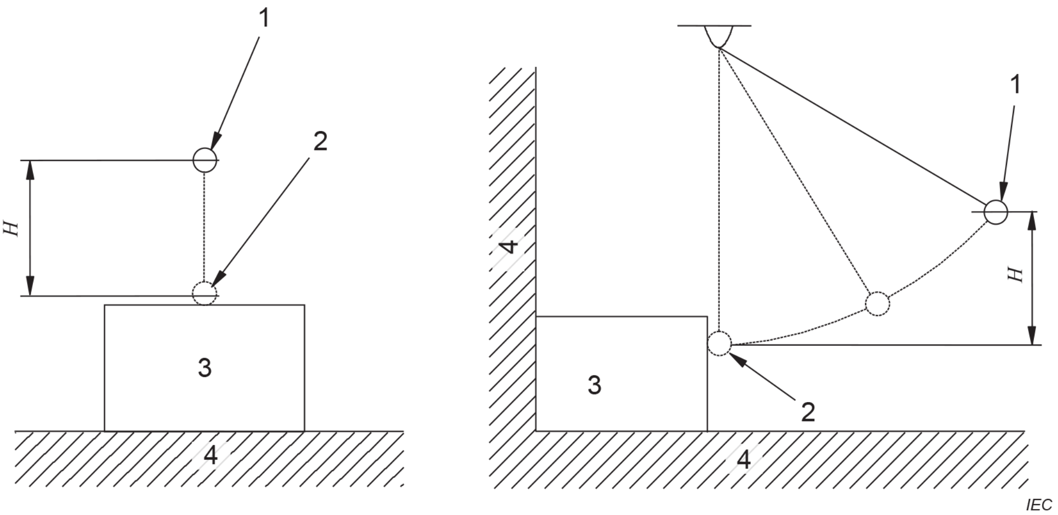
De plus, cette bille en acier est suspendue à un cordon et balancée comme un pendule afin d'appliquer un choc horizontal, en la laissant tomber d'une hauteur (H) de 1,3 m (voir la Figure 13) sur l'échantillon. Les surfaces horizontales ne sont pas concernées par cet essai.

L'échantillon est préconditionné pendant 3 h à la température la plus basse spécifiée par le fabricant pour le fonctionnement, le stockage ou le transport. La température de l'échantillon est ensuite laissée augmenter jusqu'à la température de fonctionnement la plus basse et maintenue ainsi pendant 3 h, puis immédiatement soumise à l'essai après le préconditionnement dans les conditions de laboratoire normales, comme cela est spécifié dans le Tableau 24.

Si l'analyse indique que le résultat est le même que celui d'un *BDM/CDM/PDS* non pivoté, l'échantillon peut par ailleurs être pivoté de 90° autour de chacun de ses axes horizontaux, et la bille lâchée comme dans l'essai d'impact vertical.

NOTE Au Canada, les exigences suivantes s'appliquent.

- Toutes les surfaces doivent être soumises à l'essai d'impact vertical.
- Pour une *enveloppe* dont la surface est supérieure à 260 cm^2, l'impact doit être produit par la chute de la même sphère d'une hauteur de 2 600 mm.
- Trois échantillons doivent être soumis à l'essai à la température ambiante du Tableau 24.
- Trois échantillons doivent être refroidis à 0 °C et maintenus à cette température pendant 3 h. Immédiatement après avoir été retirés de la chambre froide, les échantillons doivent être soumis à l'essai de choc à la température ambiante du Tableau 24.



Légende

1 position de départ de la bille d'acier

2 position d'impact de la bille d'acier

3 échantillon d'essai

4 surface de support rigide

Figure 13 – Essai de choc à l'aide d'une bille d'acier

5.2.2.4.4 Essai de chute (*essai de type*)

Un *BDM/CDM/PDS* portatif, un *BDM/CDM/PDS* enfichable directement et un *BDM/CDM/PDS déplaçable* d'une masse maximale de 18 kg sont soumis à l'essai suivant.

Un échantillon de *BDM/CDM/PDS* complet est soumis à un choc sur chaque position des 3 coins, 3 bords et chaque face, après avoir été lâché sur une surface horizontale suffisamment rigide.

Les éléments suivants sont considérés comme étant des surfaces horizontales suffisamment rigides pour l'essai de chute:

- une planche en bois dur d'au moins 13 mm d'épaisseur, montée sur deux couches de contreplaqué de 19 mm à 20 mm d'épaisseur chacune, le tout posé sur un sol en béton ou un sol non résilient équivalent, ou
- une planche en bois dur de 50 mm d'épaisseur, présentant une densité supérieure à 700 kg/m^3, et posée à plat sur une base rigide (un sol en béton ou un sol non résilient équivalent).

La hauteur de chute doit être

- de 1 000 mm pour les *BDM/CDM/PDS* portatifs et enfichables directement, et
- de 750 mm pour les *BDM/CDM/PDS* déplaçables.

NOTE Les exigences d'essai et la sévérité sont alignées sur l'IEC 60068-2-31:2008, 5.2 (procédure de chute libre 1), en prenant en considération le produit non emballé.

5.2.2.4.5 Essai de déformation par réduction des contraintes de moulage (*essai de type*)

Lorsque cela est exigé en 4.12.7, la conformité des *enveloppes* en matières plastiques thermomoulées ou thermoformées doit être vérifiée par la procédure d'essai décrite ci-après ou par l'*inspection visuelle* du 5.2.1 de la construction et des données disponibles, le cas échéant.

Un échantillon composé du *BDMCDM/PDS* complet ou de l'*enveloppe* complète accompagné(e) d'un châssis support, est soumis à l'essai à une température de 10 K supérieure à la température maximale de l'*enveloppe* pendant l'essai d'échauffement du 5.2.3.10, mais en aucun cas inférieure à 70 °C, puis est laissé refroidir à la température ambiante.

NOTE De plus amples informations peuvent être consultées dans l'IEC 60695-10-3.

Pour les *BDM/CDM/PDS* dont l'encombrement rend impossible l'essai de l'*enveloppe* complète, il est permis d'utiliser la partie de l'*enveloppe* représentative de l'assemblage complet quant à l'épaisseur, à la forme et à la présence éventuelle de pièces mécaniques de support.

5.2.2.5 Essai des *BDM/CDM/PDS* fixés au mur ou au plafond (*essai de type*)

Lorsque cela est exigé en 4.12.1, il doit être démontré que les *BDM/CDM/PDS* présentent une résistance mécanique adaptée pour l'usage prévu, par l'essai du 5.2.2.5, ou par calcul ou simulation.

Le *BDM/CDM/PDS* doit être monté selon les instructions selon 5.1.5.4.

Une force extérieure ajoutée à la masse du *BDM/CDM/PDS* est appliquée pendant 1 min de haut en bas en passant par le centre géométrique du *BDM/CDM/PDS* (en haut ou en bas).

La force supplémentaire doit être égale à 3 fois la masse du *BDM/CDM/PDS*, mais en aucun cas inférieure à 50 N. Le *BDM/CDM/PDS* et ses dispositifs de montage associés ne doivent pas être endommagés pendant l'essai.

La conformité doit être démontrée par un essai selon 5.2.2.5 ou par calcul ou simulation.

5.2.2.6 Essai de fixation des poignées et organes de contrôle manuels (*essai de type*)

Les poignées et organes de contrôle manuel doivent être soumis à un essai manuel et en essayant d'enlever la poignée, le bouton, la manette ou le levier par application pendant 1 min d'une force axiale comme cela est indiqué dans le Tableau 26.

Tableau 26 – Valeurs de traction pour la fixation des poignées et organes de contrôle manuels

	Effort de traction improbable N			Effort de traction probable N		
Destiné à une manœuvre par	Doigts	1 main	2 mains	Doigts	1 main	2 mains
Moyens de fonctionnement des *composants* [a]	15	100	200	30	150	300
Autre	20	150	300	50	200	450

[a] Poignées, boutons, manettes, leviers et organes analogues destinés à actionner des *composants* (soupapes, poignées d'interrupteur électrique, etc.).

Pendant les essais du Tableau 26, les poignées, les boutons, les manettes, les leviers et les organes analogues doivent être fixés au *BDM/CDM/PDS* comme prévu.

5.2.2.7 Essai de relâchement des contraintes (essai de type)

5.2.2.7.1 Réalisation de l'essai

Chaque support d'attache du 4.12.6 et dispositif d'arrêt de traction et de torsion du 4.11.10.2.2 d'un *BDM/CDM/PDS* doit être soumis à l'essai dans chaque combinaison de cordon ou de câble et traversée. Le cordon ou le câble

a) est poussé une fois manuellement dans le *BDM/CDM*, dans toute la mesure du possible,
b) est soumis 25 fois à un essai de traction constante selon la valeur indiquée dans le Tableau 27, chaque fois appliquée pendant 1 s dans le sens le moins favorable, et
c) fait l'objet pendant 1 min d'un essai de couple de rotation selon la valeur indiquée dans le Tableau 27 et aussi proche que possible de l'extrémité externe du support d'attache ou de la traversée.

Tableau 27 – Valeurs pour les essais physiques du support d'attache de l'*enveloppe*

Masse du *BDM/CDM* kg	Force pour l'essai de traction constante N	Couple pour l'essai de couple Nm
≤ 1	30	0,10
> 1 à ≤ 4	60	0,25
> 4	100	0,35

5.2.2.7.2 Critères d'acceptation

1) Le cordon ou le câble ne doit pas avoir été endommagé.
2) Le cordon ou le câble ne doit pas s'être déplacé longitudinalement de plus de 2 mm.
3) Le point où le support d'attache serre le cordon ou le câble ne doit présenter aucun signe de déformation.
4) Les *distances d'isolement* et les *lignes de fuite* selon 4.4.7.4 et 4.4.7.5 ne doivent pas avoir été réduites en dessous des valeurs applicables.
5) Le cordon ou le câble doit passer l'essai de tension en courant alternatif ou en courant continu du 5.2.3.4 comme suit:
   a) pour les BDM/CDM/PDS avec un *conducteur de mise à la terre de protection*;
      i) l'essai est réalisé entre le *conducteur de mise à la terre de protection* et les conducteurs de phase et de neutre reliés ensemble, avec la tension d'essai correspondant à la *protection principale*, et

ii) la continuité entre les *parties accessibles* conductrices et le *conducteur de mise à la terre de protection* doit être soumise à l'essai selon 5.2.3.11.2;

b) pour les *BDM/CDM/PDS* sans *conducteur de mise à la terre de protection*, l'essai est réalisé entre les *parties accessibles* conductrices du *BDM/CDM/PDS* et les conducteurs de phase et de neutre reliés ensemble, avec la tension d'essai correspondant à la *protection renforcée*.

5.2.2.8 Essai des dispositifs d'isolation et de l'intégrité du *verrouillage* (*essai de type*)

5.2.2.8.1 Réalisation de l'essai des dispositifs d'isolation

Lorsque cela est exigé par 4.4.10.1 et 4.4.10.2.1.1, tous les dispositifs d'isolation doivent être soumis à 1 000 manœuvres d'ouverture et de fermeture mécaniques à vide. Toutes les 100 manœuvres, il doit être confirmé que toutes les fonctions de *verrouillage* sont opérantes en tentant d'ouvrir des portes, de faire fonctionner des circuits électriques ou d'exécuter toute autre manœuvre que le *verrouillage* a vocation à empêcher.

Si des *composants* de déchargement sont utilisés, il doit être déterminé que

a) le dispositif ne peut pas être inséré en étant mal aligné, permettant le fonctionnement du dispositif en compromettant l'efficacité du *verrouillage*, et

b) que le dispositif ne peut pas être retiré en position fermée.

Dans le cas d'un *composant* de déchargement, une manœuvre doit être composée d'un cycle de retrait à partir d'une position totalement engagée vers la position isolée, puis d'un retour en position totalement engagée.

Les efforts exigés pour exécuter la première et la 1 000^{e} manœuvres doivent être sensiblement identiques. À l'issue de la 1 000^{e} manœuvre, l'état mécanique de l'échantillon doit être sensiblement le même qu'au début de l'essai.

5.2.2.8.2 Réalisation d'un essai de contacteur de déchargement

Un contacteur de déchargement qui n'est pas utilisé comme dispositif d'isolation du *BDM/CDM/PDS* doit être inséré et retiré 50 fois au total. Les efforts exigés pour exécuter la première et la 50^{e} manœuvres doivent être sensiblement identiques. À l'issue de la 50^{e} manœuvre, l'état mécanique de l'échantillon doit être sensiblement le même qu'au début de l'essai.

5.2.2.8.3 Réalisation de l'essai de *verrouillage* mécanique

Si aucun dispositif d'isolation n'est prévu, les *verrouillages* mécaniques doivent être soumis à l'essai 10 fois en tentant d'accéder à tous les compartiments haute tension, de faire fonctionner les circuits électriques ou de réaliser toute autre manœuvre que le *verrouillage* a vocation à empêcher. Après l'essai, il doit être confirmé que

a) toutes les fonctions de *verrouillage* sont pleinement opérantes, et

b) l'état mécanique des *verrouillages* est sensiblement le même qu'au début de l'essai.

5.2.2.9 Essai de bruit acoustique (*essai de type*)

Lorsque cela est exigé en 4.10.2, la conformité est vérifiée par l'*inspection visuelle* du 5.2.1, par mesurage ou par calcul du niveau de bruit acoustique maximal selon l'ISO 3746:2010 ou l'ISO 9614-1:1993 citées en référence dans l'IEC 60034-9.

5.2.3 Essais électriques

5.2.3.1 Généralités

Les essais électriques décrits de 5.2.3.2 à 5.2.3.5 s'appliquent à l'*isolation principale*, à l'*isolation supplémentaire*, à la *double isolation* et à l'*isolation renforcée* lorsque cela est exigé par 4.4.7.4 (*distance d'isolement*) et 4.4.7.8 (*isolation solide*).

Avant de procéder à ces essais en tant qu'*essais de type* ou qu'*essais sur prélèvement*, un préconditionnement selon 5.2.6.3.2 et 5.2.6.3.4 est exigé.

Lors de la réalisation des essais électriques et de préconditionnement, la procédure préférentielle consiste à soumettre à l'essai l'ensemble du *BDM/CDM/PDS*. Toutefois, il est acceptable de soumettre à l'essai les *composants* ou sous-ensembles assurant l'*isolation principale*, l'*isolation supplémentaire*, la *double isolation* et l'*isolation renforcée* séparément. Lorsque des *composants* ou sous-ensembles sont soumis à l'essai séparément, les conditions d'essai doivent simuler les conditions les moins favorables se produisant à l'intérieur du *BDM/CDM/PDS* à la place de l'*installation*.

Si ces essais sont réalisés comme faisant partie des critères d'acceptation, alors aucun préconditionnement en vue de réaliser ces essais n'est exigé.

5.2.3.2 Essai de *tension de tenue aux chocs* (*essai de type, essai sur prélèvement*)

L’essai de *tension de tenue aux chocs* est réalisé avec une tension ayant une forme d’onde de 1,2/50 μs (voir l'IEC 61180:2016, 7.1 et 7.2) et il est destiné à simuler des surtensions d’origine atmosphérique. Il couvre également les surtensions dues aux commutations d’appareillages. Voir le Tableau 28 pour les conditions de l’essai de *tension de tenue aux chocs*.

Les essais sur les *distances d'isolement* inférieures à celles exigées par 4.4.7.4 et sur l’*isolation solide* exigés par 4.4.7.8 sont effectués comme des *essais de type* en utilisant des tensions appropriées du Tableau 29 ou du Tableau 30.

Les essais sur les *composants* et dispositifs pour la *protection renforcée* sont effectués comme un *essai de type* et un *essai sur prélèvement* avant que lesdits *composants* et dispositifs ne soient intégrés au *BDM/CDM/PDS*, en utilisant les *tensions de tenue aux chocs* énumérées à la colonne 3 ou la colonne 5 du Tableau 29 ou du Tableau 30, selon le cas.

Pour assurer que les *parafoudres* (voir 4.4.7.2.3, 4.4.7.2.4,4.4.7.3) sont en mesure de réduire les surtensions du 4.4.7.2.1, les valeurs de la colonne 2 ou de la colonne 4 du Tableau 29 ou du Tableau 30, selon le cas, sont appliquées au *BDM/CDM/PDS* en tant qu'*essai de type*. La tension de crête mesurée ne doit pas dépasser la valeur de tension inférieure suivante de la même colonne de ce tableau.

S’il est nécessaire de soumettre à l'essai une *distance d'isolement* conçue selon 4.4.7.4.3 pour des altitudes comprises entre 2 000 m et 20 000 m (au moyen de l’IEC 60664-1:2020, Tableau A.2, qui est reproduit dans le Tableau E.1) ou de soumettre à l'essai une *distance d'isolement* conçue selon 4.4.7.4.3 pour des fréquences supérieures à 30 kHz, la tension d’essai appropriée peut être déterminée à partir de cette *distance d’isolement*, en utilisant le Tableau E.2 à l’envers.

Tableau 28 – Essai de *tension de tenue aux chocs*

Objet	Conditions d'essai		
Référence d'essai	IEC 61180:2016, Article 7 et Annexe C; IEC 60664-1:2020, 6.4.4		
Référence des exigences	Selon 4.4.3.2, 4.4.5.4, 4.4.7, 4.4.7.4.4, 4.4.7.10.2, 4.4.7.10.3, 4.4.7.8.3, 5.2.2.1		
Essai de	*Distances d'isolement*, *isolation solide*, *composants* et sous-ensemble pendant l'*essai de type*.		Réduction de surtension transitoire
Préconditionnement	Pour l'*essai de type* et l'*essai sur prélèvement*, l'*isolation solide* et les *composants* pontant la *protection principale*, la *protection en cas de défaut* ou la *protection renforcée* doivent être préconditionnés une seule fois selon 5.2.3.1. Aucun préconditionnement n'est exigé pour les essais de *distance d'isolement*.		Aucune
	Les *parties actives* appartenant au même circuit doivent être reliées entre elles.		
La *tension de tenue aux chocs* doit être appliquée entre:	1) le circuit en essai et l'*environnement*; et 2) les circuits à soumettre à l'essai.		Les parties dont la réduction de la *tension de tenue aux chocs* due aux caractéristiques du circuit ou au *SPD* doivent être vérifiées.
Mesurage initial	Aucun.		
Équipement d'essai	Un générateur d'impulsions avec une impédance de sortie maximale de 2 Ω doit être utilisé, l'impédance de sortie étant spécifiée en divisant la tension de sortie de crête en circuit ouvert par le courant de crête mesuré dans les courts-circuits quelle que soit la forme d'onde de courant.		
Autre équipement d'essai	Il est admis d'utiliser un générateur d'impulsions présentant une impédance de sortie maximale de 500 Ω si la *tension de tenue aux chocs* présente une valeur de crête complète au niveau de l'objet en essai.		Aucune
Essai alternatif	Voir 5.2.3.3.		Aucune
Puissance	n'est pas appliquée aux circuits en essai.		peut être nécessaire
Type de *protection*	*Protection principale/protection en cas de défaut*	*Protection renforcée*	--
Mesurage et vérification	*Distances d'isolement* inférieures à celles exigées en 4.4.7.4.4 en cas de conditions de champ homogènes;	--	Caractéristique assignée de *tension de tenue aux chocs* réduite par le *parafoudre* ou par les caractéristiques du circuit
	Isolation solide, *protection principale* ou *protection en cas de défaut;*	*Isolation solide* *protection renforcée;*	--
	Composants et sous-ensembles en parallèle sur la *protection principale* ou la *protection en cas de défaut.*	*Composants* et dispositifs pour la *protection renforcée.*	--
Nombre d'alternances	Trois alternances de chaque polarité à un intervalle ≥ 1 s, définies sur une tension de crête minimale en circuit ouvert selon:		
Tension d'essai appropriée	Colonne 2 ou colonne 4 du Tableau 29 Colonne 2 ou colonne 4 du Tableau 30	Colonne 3 ou colonne 5 du Tableau 29 Colonne 3 ou colonne 5 du Tableau 30	Colonne 2 ou colonne 4 du Tableau 29 Colonne 2 ou colonne 4 du Tableau 30
Correction d'altitude	Quand l'essai est réalisé sur une *distance d'isolement* à une altitude inférieure à 2 000 m, la tension d'essai doit être augmentée selon l'IEC 60664-1:2020, Tableau F.6, qui est reproduit dans le Tableau E.2 du présent document.		
	Le facteur de correction d'altitude ne s'applique pas à l'essai de *tension de tenue aux chocs* sur l'*isolation solide* selon l'IEC 60664-1:2020, 6.4.4.1.		

L'essai de *tension de tenue aux chocs* est satisfaisant si aucune perforation de l'*isolation*, aucun contournement ou aucune décharge disruptive ne se produit. Concernant les *composants* et dispositifs qui utilisent une *isolation* solide pour la *protection renforcée*, un essai ultérieur de décharge partielle (voir 5.2.3.5) doit également être effectué avec succès si cela est exigé par 4.4.7.10.3.

Il existe une alternative pour les *BDM/CDM/PDS haute tension*. L'essai de *tension de tenue aux chocs* est réussi si

a) 3 chocs consécutifs ont été appliqués pour chaque polarité et
   - il n'est pas apparu de décharge disruptive, ou
   - une décharge apparaît dans la partie de l'*isolation* autorégénératrice, puis neuf chocs supplémentaires ont alors été appliqués sans apparition de décharge disruptive, ou
b) 15 chocs consécutifs ont été appliqués pour chaque polarité et
   - le nombre de décharges disruptives sur l'*isolation* autorégénératrice ne dépasse pas deux pour chaque série, et
   - il n'apparaît pas de décharge disruptive sur l'*isolation* non autorégénératrice.

Tableau 29 – Tension de l'essai de *tension de tenue aux chocs* pour les *BDM/CDM/PDS basse tension*

Colonne 1	**2**	**3**	**4**	**5**
***Tension système* (voir 4.4.7.1.7)**	***Tension de tenue aux chocs* pour l'*isolation* entre les circuits connectés à l'alimentation non raccordée directement au *réseau* et leur *environnement* selon la catégorie de surtension II**		***Tension de tenue aux chocs* pour l'*isolation* entre les circuits connectés au *réseau* et leur *environnement* selon la catégorie de surtension III**	
V	***Isolation principale* ou *isolation supplémentaire*** V	***Isolation renforcée*** V	***Isolation principale* ou *isolation supplémentaire*** V	***Isolation renforcée*** V
≤ 50	500	800	800	1 500
100	800	1 500	1 500	2 500
150	1 500	2 500	2 500	4 000
300	2 500	4 000	4 000	6 000
600	4 000	6 000	6 000	8 000
1 000	6 000	8 000	8 000	12 000
-	Interpolation admise		Interpolation non admise	
NOTE 1 Les tensions d'essai pour la catégorie de surtension I et la catégorie de surtension III (colonne 2 et colonne 3) peuvent être déduites de façon similaire à partir du Tableau 6.				
NOTE 2 Les tensions d'essai pour la catégorie de surtension II et la catégorie de surtension IV peuvent être déduites de façon similaire à partir du Tableau 6.				

Tableau 30 – Tension de l'essai de *tension de tenue aux chocs* pour les *BDM/CDM/PDS haute tension*

Colonne 1	**2**	**3**	**4**	**5**
Tension système **(voir 4.4.7.2.1)**	***Tension de tenue aux chocs*** **pour l'*isolation* entre les circuits et leur *environnement* selon la catégorie de surtension III**		***Tension de tenue aux chocs*** **pour l'*isolation* entre les circuits et leur *environnement* selon la catégorie de surtension IV**	
V	***Isolation principale* ou *isolation supplémentaire*** V	***Isolation renforcée*** V	***Isolation principale* ou *isolation supplémentaire*** V	***Isolation renforcée*** V
> 1 000	8 000	12 800	12 000	19 200
3 600	20 000	32 000	40 000	64 000
7 200	40 000	64 000	60 000	96 000
12 000	60 000	96 000	75 000	120 000
17 500	75 000	120 000	95 000	152 000
24 000	95 000	152 000	125 000	200 000
36 000	125 000	200 000	145 000	232 000

Interpolation admise.

NOTE Les tensions d'essai pour la catégorie de surtension I et la catégorie de surtension II peuvent être déduites de façon similaire du Tableau 6.

5.2.3.3 Alternative à l'essai de *tension de tenue aux chocs* (*essai de type, essai sur prélèvement*)

Si cela est admis dans le Tableau 28, un essai de tension modifié en courant alternatif ou en courant continu selon 5.2.3.4 peut être utilisé comme alternative à l'essai de *tension de tenue aux chocs* du 5.2.3.2.

Pour un essai de tension en courant alternatif, la valeur de crête de la tension d'essai en courant alternatif doit être égale à la tension de l'essai de *tension de tenue aux chocs* du Tableau 29 ou du Tableau 30, selon le cas, et être appliquée pour trois cycles de la tension d'essai en courant alternatif.

Pour un essai de tension en courant continu, la valeur moyenne de la tension d'essai en courant continu doit être égale à la tension de l'essai de *tension de tenue aux chocs* du Tableau 29 ou du Tableau 30, selon le cas, et être appliquée 3 fois pendant 10 ms dans chaque polarité.

Le temps de rampe doit satisfaire au Tableau 34.

Voir l'IEC 60664-1:2020, 6.2.2.1.3, pour des informations complémentaires.

La correction d'altitude s'applique selon le Tableau 28.

5.2.3.4 Essai de tension en courant alternatif ou en courant continu (*essai de type* et *individuel de série*)

5.2.3.4.1 But de l'essai

L'*essai de type* est utilisé pour vérifier que les *distances d'isolement* et l'*isolation solide* des *composants* et des *BDM/CDM/PDS* assemblés possèdent une rigidité diélectrique appropriée permettant de résister aux conditions de *surtension temporaire*.

L'*essai individuel de série* est exécuté pour vérifier que les *distances d'isolement* n'ont pas été réduites pendant le processus de fabrication.

NOTE Aux États-Unis, l'essai de tension en courant alternatif ou en courant continu est exigé en tant qu'*essai de type*, pas en tant qu'*essai individuel de série*.

5.2.3.4.2 Valeur et type de la tension d'essai

Les valeurs de la tension d'essai sont déterminées dans la colonne 2 ou la colonne 3 du Tableau 31, du Tableau 32, ou du Tableau 33, selon que le circuit en essai est connecté au *réseau basse tension*, au *réseau* haute tension ou à l'*alimentation non raccordée directement au réseau*.

La tension d'essai de la colonne 2 est utilisée pour soumettre à l'essai les circuits ayant une *protection principale*.

Entre les circuits avec *protection renforcée* (*double isolation* ou *isolation renforcée*), la tension d'essai de la colonne 3 doit être appliquée pour l'*essai de type*. Pour les *essais individuels de série* entre les circuits avec *protection renforcée*, les valeurs de la colonne 2 doivent être appliquées afin de prévenir tout dommage de l'*isolation solide* par décharge partielle.

Les valeurs de la colonne 3 doivent s'appliquer au *BDM/CDM/PDS* avec une *protection renforcée* selon 4.4.5.

Pour les circuits connectés à l'*alimentation non raccordée directement au réseau* dans laquelle des *surtensions temporaires* sont présentes, la tension d'essai doit être comme suit:

- pour réaliser les *essais de type* des circuits avec *protection principale*, et pour tous les *essais individuels de série*: la *surtension temporaire* (valeur efficace courant alternatif ou courant continu) telle que déterminée en 4.4.7.2.4;
- pour réaliser les *essais de type* des circuits avec *protection renforcée*, et entre les circuits et les surfaces accessibles (non conductrices ou conductrices mais non raccordées à la terre de protection, *protection de classe II* selon 4.4.6.3): 1,6 fois la *surtension temporaire* (valeur efficace courant alternatif ou courant continu) telle que déterminée en 4.4.7.2.4.

Pour les circuits *non raccordés directement au réseau*, dans lesquels les *surtensions temporaires* ne sont pas présentes, les tensions d'essai sont déterminées à partir du Tableau 33, en fonction de la *tension de fonctionnement*.

L'essai de tension doit être effectué avec une tension sinusoïdale de 50 Hz ou 60 Hz. Si le circuit contient des condensateurs, l'essai peut être effectué avec une tension continue égale à la valeur de crête de la tension alternative spécifiée.

Pour un circuit à connexion galvanique tant au *réseau* qu'à l'*alimentation non raccordée directement au réseau*, les tensions d'essai sont déterminées en prenant en considération le résultat le plus défavorable de l'utilisation de la *tension système* du *réseau* déterminée à partir de la colonne 2 et de la colonne 3 du Tableau 31, et le résultat de la *tension de fonctionnement* de crête répétitive de l'*alimentation non raccordée directement au réseau* déterminée à partir du Tableau 33.

Tableau 31 – *Tension d'essai alternative ou continue pour circuits raccordés directement au réseau basse tension*

Colonne 1 ***Tension système* pour la *surtension temporaire* (voir 4.4.7.1.7 a))**	**2** **Tension pour *essais de type* des circuits avec *protection principale* et pour tous les *essais individuels de série***		**3** **Tension pour *essais de type* des circuits avec *protection renforcée* et entre les circuits et les surfaces accessibles (non conductrices ou conductrices mais non raccordées à la terre de protection, *protection de classe II* selon 4.4.6.3)**	
V	**Valeur efficace courant alternatif [a]** V	**Courant continu** V	**Valeur efficace courant alternatif** V	**Courant continu** V
≤ 50	1 250	1 770	2 500	3 540
100	1 300	1 840	2 600	3 680
150	1 350	1 910	2 700	3 820
300	1 500	2 120	3 000	4 240
600	1 800	2 550	3 600	5 090
1 000	2 200	3 110	4 400	6 220

Interpolation admise.

Il est recommandé d'utiliser l'équipement d'essai comme cela est indiqué dans l'IEC 61180:2016.

[a] Correspondant à 1 200 V + *tension système*.

Tableau 32 – Tension d'essai alternative ou continue pour circuits raccordés directement au *réseau haute tension*

Colonne 1 **Entre phases *Tension système* (voir 4.4.7.1.7 b))**	**2** **Tension pour *essais de type* des circuits avec *protection principale* et pour tous les *essais individuels de série***		**3** **Tension pour *essais de type* des circuits avec *protection renforcée* et entre les circuits et les surfaces accessibles (non conductrices ou conductrices mais non raccordées à la terre de protection, *protection de classe II* selon 4.4.6.3)**	
V	**Valeur efficace courant alternatif [a]** V	**Courant continu** V	**Valeur efficace courant alternatif** V	**Courant continu** V
> 1 000	3 000	4 250	4 800	6 800
3 600	10 000	14 150	16 000	22 650
7 200	20 000	28 300	32 000	45 300
12 000	28 000	39 600	44 800	63 350
17 500	38 000	53 700	60 800	85 900
24 000	50 000	70 700	80 000	113 100
36 000	70 000	99 000	112 000	158 400

Interpolation admise.

Il est recommandé d'utiliser l'équipement d'essai comme cela est indiqué dans l'IEC 61180:2016.

[a] Valeurs issues de l'IEC 60071-1:2019, Tableau 2.

Tableau 33 – Tension d'essai alternative ou continue pour les circuits raccordés à l'*alimentation non raccordée directement au réseau* sans *surtension temporaire*

Colonne 1 *Tension de fonctionnement* (crête répétitive) (voir 4.4.7.1.7.2)	2 Tension pour *essais de type* des circuits avec *protection principale* et pour tous les *essais individuels de série*		3 Tension pour *essais de type* des circuits avec *protection renforcée* et entre les circuits et les surfaces accessibles (non conductrices ou conductrices mais non raccordées à la terre de protection, *protection de classe II* selon4.4.6.3)	
V	Valeur efficace courant alternatif V	Courant continu V	Valeur efficace courant alternatif V	Courant continu V
≤ 71	80	110	160	220
141	160	225	320	450
212	240	340	480	680
330	380	530	760	1 100
440	500	700	1 000	1 400
600	680	960	1 400	1 900
1 000	1 100	1 600	2 200	3 200
1 600	1 800	2 600	2 900	4 200
2 300	2 600	3 700	4 200	5 900
3 000	3 400	4 800	5 400	7 700
4 600	5 200	7 400	8 300	11 800
7 600	8 500	12 000	14 000	19 000
16 000	18 000	26 000	29 000	42 000
23 000	26 000	37 000	42 000	59 000
30 000	34 000	48 000	54 000	77 000
38 000	43 000	61 000	69 000	98 000
50 000	57 000	80 000	91 000	130 000
60 000	70 000	99 000	109 000	154 000

Interpolation admise.

Il est recommandé d'utiliser l'équipement d'essai comme cela est indiqué dans l'IEC 61180:2016.

NOTE Les tensions d’essai de ce tableau sont fondées sur 80 % de la tension de tenue pour la *distance d'isolement* correspondante du Tableau 8 comme cela est indiqué par l’IEC 60664-1:2020, Tableau A.1.

5.2.3.4.3 Considérations d'essai supplémentaires

Les dispositifs de protection conçus pour réduire les *tensions de tenue aux chocs* sur les circuits soumis à des essais (voir 4.4.7.2.3 et 4.4.7.2.4), et les circuits appartenant aux circuits de surveillance ou de protection, qui ne sont pas conçus pour supporter la surtension d’essai pendant la durée de l’essai, doivent être déconnectés pour éviter les dommages et pour assurer que la tension de l’essai peut être appliquée sans fausse indication de défaut.

Dans tous les cas réalisables, il convient que les *composants* individuels formant partie intégrante de l’isolation soumise à l’essai (par exemple les condensateurs de suppression d’interférences) ne soient pas déconnectés ou pontés avant l’essai. Dans ce cas, il est recommandé d’utiliser la tension d’essai en courant continu selon 5.2.3.4.2.

Si les essais ne sont pas possibles dans les *BDM/CDM/PDS* assemblés en raison d'une faible impédance des *impédances de protection* ou d'un *SPD* qui n'est pas conçu pour supporter la tension d'essai pendant la durée de l'essai, la connexion aux *impédances de protection* ou au *SPD* doit être ouverte avant les essais. Dans ce dernier cas, la connexion doit être rétablie avec la plus grande prudence à l'issue de l'essai de tension.

Les *impédances de protection* selon 4.4.5.4 doivent être incluses dans les essais ou la liaison avec la partie séparée et protégée du circuit doit être ouverte avant de procéder aux essais. Dans ce dernier cas, la connexion doit être rétablie à l'issue de l'essai de tension avec la plus grande prudence afin d'éviter tout dommage de l'*isolation*.

5.2.3.4.4 Exécution de l’essai de tension

L’essai doit être appliqué comme suit, selon la Figure 14.

a) Essai (1) entre la *partie accessible* conductrice (reliée à la terre) et chaque circuit de manière séquentielle (excepté les circuits *CTD A*s). La tension d’essai est conforme au Tableau 31, au Tableau 32 ou au Tableau 33, colonne 2, et correspond à la tension du circuit concerné soumis à l’essai.

   Essai (2) entre la surface accessible (non conductrice ou conductrice mais non reliée à la terre) et chaque circuit de manière séquentielle (excepté les circuits *CTD As*). La tension d’essai est conforme au Tableau 31, au Tableau 32 ou au Tableau 33, colonne 3 (pour l’*essai de type*) ou colonne 2 (pour l’*essai individuel de série*) et correspond à la tension du circuit concerné soumis à l’essai.

b) Essai entre chaque circuit concerné de manière séquentielle et les autres *circuits adjacents* reliés entre eux (excepté les circuits *CTD As*). La tension d’essai est conforme au Tableau 31, au Tableau 32 ou au Tableau 33, colonne 2, et correspond à la tension du circuit concerné soumis à l’essai.

c) Essai entre un circuit *CTD As* et chaque *circuit adjacent* de manière séquentielle. La tension d’essai est conforme au Tableau 31, au Tableau 32 ou au Tableau 33, colonne 3 (pour les *essais de type*) ou colonne 2 (pour les *essais individuels de série*) et correspond au circuit ayant la plus forte tension. Le *circuit adjacent* ou le circuit *CTD As* peut être relié à la terre pour cet essai. Il est nécessaire de soumettre à l'essai l’*isolation principale* entre la CTD As et les circuits *TBTP* et les *circuits TBTS*, mais il n’est pas nécessaire de soumettre à l'essai l'*isolation fonctionnelle* entre les circuits *TBTP adjacents* ou les circuits *TBTS adjacents*.

Étant donné que la CTD As et les *circuits TBTP* ou TBTS et les circuits de la CTD C et de la CTD D sont en général séparés du châssis (terre) par l'*isolation principale*, il est souvent impossible de soumettre à l'essai la *double isolation* ou l'*isolation renforcée* qui sépare la CTD et les *circuits TBTP* ou les *circuits* TBTS des circuits CTD C et CTD D dans un PDS entièrement assemblé sans surcharger l'*isolation principale*. En raison de cela, il peut être nécessaire de démonter le PDS, ou il peut être impossible d’effectuer des *essais de type* sur l’isolation de protection à des tensions conformes à la colonne 3 du Tableau 31 ou du Tableau 33. Dans ces cas, l’*essai de type* de l’isolation utilisée pour la protection renforcée doit être réalisé à des tensions conformes à la colonne 2 du tableau approprié.

NOTE L'essai de la *double isolation* ou de l'*isolation renforcée* est réalisé sur le *composant* séparément.

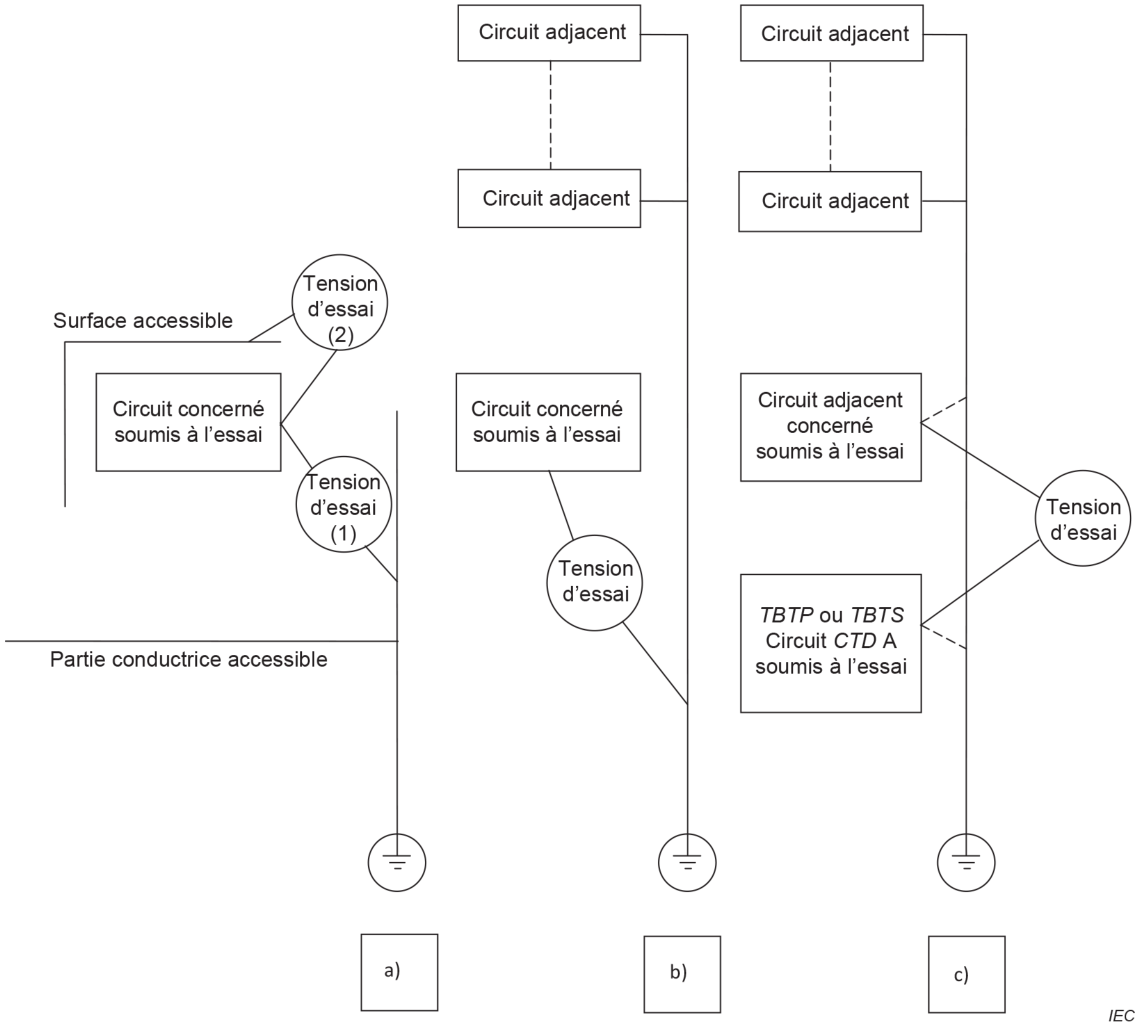


Figure 14 – Procédures d'essais de tension

Les essais doivent être réalisés avec les portes de l'*enveloppe* fermées et avec tous les *capots de l'enveloppe* en place.

Lorsque le circuit est connecté électriquement aux *parties accessibles* conductrices, l'essai de tension n'est pas pertinent et peut être omis.

Pour créer un circuit continu pour la tension d'essai sur le *PDS*, les bornes, les contacts ouverts de commutateurs et de dispositifs à semiconducteur, etc. doivent être pontés si nécessaire. Avant de procéder à l'essai, les dispositifs à semiconducteur et autres *composants* vulnérables à l'intérieur d'un circuit peuvent être déconnectés et/ou leurs bornes peuvent être pontées pour éviter qu'ils ne soient endommagés pendant l'essai.

Lorsque le *BDM/CDM/PDS* est couvert totalement ou partiellement par une surface accessible non conductrice, une feuille conductrice, à laquelle est appliquée la tension d'essai, doit être enroulée autour de cette surface d'essai. Dans ce cas, l'essai d'*isolation* entre un circuit et une surface accessible non conductrice peut être effectué dans le cadre d'un *essai sur prélèvement* en lieu et place d'un *essai individuel de série*.

Le potentiel de sortie appliqué doit être mesuré et surveillé tout au long de l'essai.

Les écrans de protection selon 4.4.4.7 doivent rester reliés aux *parties accessibles* conductrices pendant l'essai de tension.

L'*essai individuel de série* du *BDM/CDM/PDS* assemblé n'est pas exigé si

- *l'essai individuel de série* pour tous les sous-ensembles liés au système d'*isolation* du *BDM/CDM/PDS* est réalisé,
- il peut être démontré que l'assemblage final ne compromet pas le système d'*isolation*, et
- les *essais de type* du *BDM/CDM/PDS* entièrement assemblé ont été effectués avec succès.

5.2.3.4.5 Durée de l'essai de tension en courant alternatif ou en courant continu

Pour les *BDM/CDM/PDS*, les paramètres d'essai sont indiqués dans le Tableau 34 pour l'*essai de type* et pour l'*essai individuel de série*.

Tableau 34 – Paramètre pour l'essai de tension en courant alternatif ou en courant continu du *BDM/CDM/PDS*

BDM/CDM/PDS	Temps de rampe haut et bas	Durée de tension complète *essai de type* et *essai individuel de série*	Tension d'essai
Basse tension	≥ 1 s	60 s [a]	Tableau 31 ou Tableau 33
Haute tension	≥ 5 s	5 s [a]	Tableau 32 [b]

[a] Pour l'*essai individuel de série* uniquement, la durée de l'essai peut être réduite à 1 s.

[b] Si l'essai de tension a déjà été réalisé avec succès à 100 % de la tension d'essai, et qu'il est exigé comme critère d'acceptation de l'autre *essai de type*, la tension peut être ramenée à 80 % de la tension d'essai d'origine.

5.2.3.4.6 Vérification de l'essai de tension en courant alternatif ou en courant continu

L'essai est satisfaisant si aucun *claquage électrique* n'intervient pendant l'essai.

5.2.3.5 Essai de décharge partielle (*essai de type*, *essai sur prélèvement*)

L'essai de décharge partielle doit confirmer que l'*isolation solide* (voir 4.4.7.8) utilisée dans les *composants* et les sous-ensembles pour la *protection renforcée* des circuits électriques demeure exempte de toute décharge partielle dans la plage de tensions spécifiée (voir le Tableau 35).

NOTE Aux États-Unis, les essais de décharge partielle ne sont pas exigés.

Cet essai doit être effectué comme *essai de type* et un *essai sur prélèvement* comme cela est spécifié en 4.4.7.10. Il peut être ignoré pour les matériaux isolants qui ne sont pas abîmés par des décharges partielles (la céramique ou le verre, par exemple).

La tension de seuil de décharge partielle et la tension d'extinction de décharge partielle sont influencées par les facteurs climatiques (par exemple température et humidité), l'autoéchauffement des appareillages et la tolérance de fabrication. Ces variables peuvent être importantes dans certaines conditions et doivent par conséquent être prises en compte au cours d'un *essai de type*.

Tableau 35 – Essai de décharge partielle

Objet	Conditions d'essai
Référence d'essai	IEC 60664-1:2020, 6.4.6
Référence des exigences	4.4.7.8
Préconditionnement	Le préconditionnement selon 5.2.3.1 doit être réalisé pour l'*essai de type* et l'*essai sur prélèvement*. L'essai de *tension de tenue aux chocs* 5.2.3.2 doit être réalisé comme un préconditionnement avant de procéder à la décharge partielle. Les *parties actives* appartenant au même circuit doivent être reliées entre elles. Il est recommandé de réaliser l'essai de décharge partielle avant d'intégrer les *composants* ou les dispositifs au *BDM/CDM/PDS*, du fait que l'essai de décharge partielle n'est normalement pas possible lorsque le *BDM/CDM/PDS* est assemblé.
Mesurage initial	Selon spécification du *composant* ou dispositif
Équipement d'essai	Dispositif de mesure de la charge étalonnée ou appareil de mesure des interférences radioélectriques sans filtre de pondération
Circuit d'essai Tension d'essai Méthode d'essai	IEC 60664-1:2020, Article C.1 La valeur de crête du courant alternatif 50 Hz ou 60 Hz IEC 60664-1:2020, 6.4.6.1: F_1 = 1,2; F_2, F_3 = 1,25. Procédure d'essai IEC 60664-1:2020, 6.4.6.3
Étalonnage de l'équipement d'essai	IEC 60664-1:2020, Article C.4
Mesurage et vérification	En commençant avec une valeur de tension inférieure à la tension d'essai de décharge partielle assignée U_{PD} [a], la tension doit être augmentée de façon linéaire jusqu'à 1,875 fois U_{PD} et maintenue pendant une durée maximale de 5 s (voir la Figure 15). La tension doit être diminuée de façon linéaire jusqu'à 1,5 fois U_{PD} (± 5 %) et maintenue pendant une durée maximale de 15 s, au cours de laquelle la décharge partielle est mesurée.
NOTE 1 L'essai de décharge partielle de l'*isolation solide* avec une *tension de fonctionnement* en courant continu selon A.5.4 peut être ignoré. NOTE 2 Bien que la norme de référence soit limitée aux *BDM/CDM/PDS basse tension*, cette procédure d'essai est étendue aux *BDM/CDM/PDS haute tension* couverts par le présent document.	
[a] La tension d'essai de décharge partielle assignée U_{PD} est la tension de crête répétitive mesurée sur l'*isolation*.	

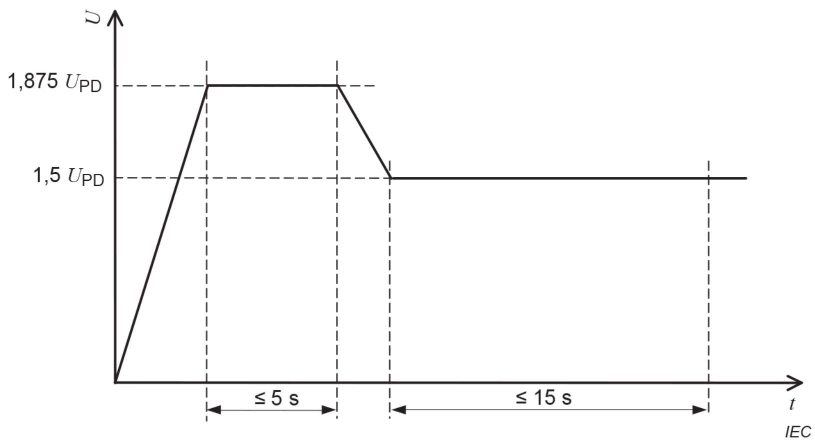


Figure 15 – Procédure d'essai de décharge partielle

L'essai doit être considéré comme satisfaisant si la décharge partielle est inférieure à 10 pC pendant la période de mesure.

Des valeurs inférieures à 10 pC sont exigées pour un système d'isolation qui, compte tenu de sa construction, peut être endommagé en raison du vide d'air lorsqu'il est exposé à la contrainte de tension (résine coulée, empotage, moulage, fil à triple isolation, etc.).

Aucun critère d'acceptation n'est défini pour les décharges en couronne dans l'air.

5.2.3.6 Essai d'*impédance de protection* (*essai de type, essai individuel de série*)

Un *essai de type* doit être effectué pour vérifier que le courant circulant dans une *impédance de protection*, dans des conditions de fonctionnement normal ou des *conditions de premier défaut*, ne dépasse pas les valeurs indiquées en 4.4.5.4.

NOTE 1 Aux États-Unis et au Canada, l'essai d'*impédance de protection* est exigé en tant qu'*essai de type*, pas en tant qu'*essai individuel de série*.

L'essai doit être réalisé en utilisant le circuit de l'IEC 60990:2016, Figure 4 (voir la Figure L.1), ou en mesurant le courant à travers l'*impédance de protection* vers la *terre de protection*.

NOTE 2 L'IEC 60990 indique que l'utilisation d'un réseau unique pour les mesurages d'un courant alternatif associé à un courant continu n'a pas été étudiée, mais aucune suggestion n'est faite pour les mesurages dans de tels cas.

La valeur de l'*impédance de protection* doit être vérifiée dans un *essai individuel de série*.

NOTE 3 La valeur de l'*impédance de protection* peut être vérifiée lors du processus de fabrication.

5.2.3.7 Essai de mesure du *courant de contact* (*essai de type*)

Le *courant de contact* doit être mesuré afin de déterminer si les mesures du 4.4.4.3.3 sont applicables, sauf si l'une des mesures du 4.4.4.3.3 a) ou b) est utilisée. LE *BDM/CDM/PDS* doit être isolé sans aucune connexion à la terre et doit être utilisé à la tension assignée. Dans ces conditions, le *courant de contact* doit être mesuré entre le dispositif de raccordement du *conducteur de mise à la terre de protection* et le *conducteur de mise à la terre de protection* lui-même avec le circuit d'essai de l'IEC 60990:2016, Figure 4 (voir la Figure L.1).

a) Pour un *BDM/CDM/PDS* à relier à un *réseau* avec neutre mis à la terre, le neutre du réseau du site d'essai doit être directement relié au *conducteur de mise à la terre de protection*.
b) Pour un *BDM/CDM/PDS* à relier à un *réseau* isolé ou à un *réseau* à impédance, le neutre doit être relié par une résistance de 1 kΩ au *conducteur de mise à la terre de protection* qui doit être relié à chaque phase d'entrée tour à tour. La valeur la plus élevée doit être considérée comme le résultat définitif.
c) Pour un *BDM/CDM/PDS* devant être relié à un réseau "corner-earthed", le *conducteur de mise à la terre de protection* doit être relié à chaque phase d'entrée tour à tour. La valeur la plus élevée doit être considérée comme le résultat définitif.
d) Pour un *BDM/CDM/PDS* avec un *système* de mise à la terre spécifique, ce *système* doit fonctionner comme cela a été prévu pendant l'essai.
e) Si un *BDM/CDM/PDS* est destiné à être connecté à plusieurs *systèmes*, chacun de ces *systèmes* différents (ou le cas le plus défavorable, si cela peut être déterminé) doit être utilisé pour effectuer les mesurages du *courant de contact*.

Pour un *BDM/CDM/PDS* qui peut être mis sous tension à partir de plusieurs sources d'alimentation, les limites de *courant de contact* indiquées en 4.4.4.3.3 s'appliquent dans toutes les configurations d'*installation* et combinaisons de sources possibles qui peuvent être mises sous tension en même temps.

Cet essai est réalisé en tant qu'*essai de type*.

Pour des informations, un aperçu du circuit d'essai de mesure est donné à l'Annex L.

5.2.3.8 Essai de décharge du condensateur (*essai de type*)

Le temps de décharge du condensateur exigée par 4.4.9, 4.5.2.2 et 4.11.7 doit être vérifié par cet *essai de type* et/ou par calcul en tenant compte des tolérances pertinentes.

Le *BDM/CDM/PDS* doit être relié à une alimentation à la tension assignée maximale et utilisé tant que les condensateurs en cours d'évaluation ne sont pas totalement chargés. Aucune charge ne doit être connectée, et le *BDM/CDM/PDS* doit être à l'état d'arrêt. La tension dans le condensateur doit être surveillée avant et après avoir coupé l'alimentation. Le chronométrage doit commencer dès la coupure d'alimentation et se terminer lorsque les valeurs selon 4.4.9 ou 4.5.2.2 (selon le cas) sont atteintes.

L'impédance d'entrée du dispositif de surveillance de la tension ne doit pas être inférieure à 1 MΩ.

Si les exigences du 4.4.9 et du 4.5.2.2 ne sont pas satisfaites, un marquage est exigé selon 6.5.2.

5.2.3.9 Essai de source de puissance limitée (*essai de type*)

Lorsque cela est exigé par 4.5.3, un circuit à source de tension limitée doit être soumis à l'essai comme cela est indiqué ci-après, avec le *BDM/CDM/PDS* fonctionnant dans des conditions normales de fonctionnement.

Si les exigences de la source de puissance limitée dépendent du ou des dispositifs de protection contre les *surintensités*, ces dispositifs doivent être mis en court-circuit.

La tension de sortie en circuit ouvert ne doit pas dépasser la valeur correspondante du Tableau 15 ou du Tableau 16, selon le cas.

Le *BDM/CDM/PDS* fonctionnant dans les conditions de fonctionnement normal, une charge résistive variable est reliée au circuit à l'étude et réglée de manière à obtenir un niveau légèrement supérieur au niveau de courant limite ou de puissance apparente indiqué dans le Tableau 15 ou dans le Tableau 16, selon le cas. Si nécessaire, un autre réglage est réalisé pour maintenir le niveau de courant ou de puissance apparente pendant la période indiquée dans le Tableau 15 ou dans le Tableau 16, selon le cas.

Les *conditions de premier défaut* dans un réseau régulateur selon 4.2 sont appliquées dans les conditions maximales de courant et de puissance spécifiées ci-dessus.

L'essai est satisfaisant si, après la période d'essai, le courant ou la puissance apparente disponible, selon le cas, ne dépasse pas les limites indiquées dans le Tableau 15 ou dans le Tableau 16, selon le cas.

5.2.3.10 Essai d'échauffement (*essai de type*)

Cet essai est destiné à assurer que les parties, les parties accessibles et les surfaces accessibles du *BDM/CDM/PDS* ne dépassent pas les limites de température spécifiées en 4.6.5 ni les limites de température des parties liées à la sécurité indiquées par le fabricant du *composant*.

Dans la mesure du possible, le *BDM/CDM/PDS* doit être soumis à l'essai dans les conditions les plus défavorables de puissance assignée et de *courant de sortie assigné BDM/CDM/PDS*, en tenant compte de l'allègement de régime et des caractéristiques de commande de refroidissement.

Pour déterminer si le *BDM/CDM* satisfait aux exigences d'essai de température, il doit fonctionner jusqu'à la stabilisation thermique dans les conditions normales de fonctionnement, comme suit:

a) pour un fonctionnement continu, selon les caractéristiques assignées continues;

b) pour un fonctionnement intermittent, selon le cycle de service assigné; ou

c) pour un fonctionnement de courte durée, pendant le temps de fonctionnement assigné.

Il n'est pas exigé de soumettre à l'essai un *BDM/CDM* de *type ouvert* dans une *enveloppe* si la *température de l'air ambiant environnant* est indiquée sur le marquage.

Pour les *BDM/CDM/PDS* dont l'échauffement ou le refroidissement dépend de la température (un *BDM/CDM/PDS* équipé d'un ventilateur dont la vitesse augmente à une température plus élevée, par exemple), la température doit être mesurée à la *température ambiante* la plus défavorable dans les limites de la plage de fonctionnement spécifiée du fabricant.

Le *BDM/CDM/PDS* doit être soumis à l'essai avec au moins 1,2 m de fil électrique relié à chaque *borne pour câblage externe*. Le fil doit avoir la plus petite dimension destinée à être reliée au *BDM/CDM/PDS* comme cela est spécifié par le fabricant pour l'*installation*. Lorsqu'il est prévu uniquement la connexion de bus de raccordement au *BDM/CDM/PDS*, ceux-ci doivent être de la dimension minimale destinée à être reliée au *BDM/CDM/PDS* comme cela est spécifié par le fabricant, et leur longueur doit être au moins égale à 1,2 m.

L'essai doit être maintenu jusqu'à ce que la stabilisation thermique soit atteinte. C'est-à-dire lorsque trois lectures successives, prises à intervalles de 10 % de la durée précédemment écoulée de l'essai et non inférieures à 10 min, n'indiquent aucun changement de température, soit ±1 °C entre les trois lectures successives par rapport à la *température ambiante*.

Si un danger peut être provoqué par la défaillance d'une *isolation électrique*, la température de cette *isolation* (autre que celles des enroulements) est mesurée sur la surface extérieure de l'*isolation* en un point proche de la source de chaleur. Si les températures des enroulements sont mesurées par la méthode de thermocouple, le thermocouple doit être placé sur la surface de l'enroulement en prenant pour hypothèse la partie la plus chaude due aux *composants* thermiques environnants. Voir également les notes de bas de tableau du Tableau 17.

La température maximale atteinte doit être corrigée à la *température ambiante* assignée du *BDM/CDM/PDS* en ajoutant la différence entre la *température ambiante* au cours de l'essai et la *température ambiante* assignée maximale du *BDM/CDM/PDS*.

Dans le cadre de l'essai du fonctionnement intermittent ou du fonctionnement de courte durée, le *BDM/CDM/PDS* doit être soumis à l'essai à l'aide d'une des méthodes suivantes. Le fonctionnement intermittent fonctionne cycliquement

- à la durée de cycle "MARCHE/ARRÊT" définie par le fabricant, de façon répétée, jusqu'à ce que la température maximale et la stabilité soient atteintes, ce qui prouve que la durée de cycle choisie est sans danger,
- durant un cycle "MARCHE", en surveillant et en consignant la durée exigée jusqu'à ce que toutes les températures reviennent à la température ambiante, ce qui établit une durée de vie sans danger pour le cycle "MARCHE/ARRÊT", ou
- sous un cycle d'essai défini par le fabricant qui assure que le fonctionnement intermittent ou de courte durée spécifié par le client est soumis à l'essai dans les conditions les plus défavorables, comme cela est défini par le présent document.
- L'essai de tension en courant alternatif ou en courant continu *essai individuel de série* conformément au point 5.2.3.4 doit être réussi.

Le *BDM/CDM/PDS* doit fonctionner dans les conditions de tension et de courant spécifiques du fabricant pour les caractéristiques assignées du fonctionnement intermittent.

Les fonctionnements intermittents et de courte durée peuvent dépasser le niveau de 100 % de fonctionnement continu.

La qualification de fonctionnement intermittent ou de courte durée n'annule pas l'exigence de réaliser l'essai d'échauffement à la caractéristique assignée de 100 % du *BDM/CDM/PDS*.

Il n'est pas exigé de spécifier un cycle de service de fonctionnement de courte durée ou intermittent.

Pour la conformité,

- aucune température corrigée ne doit dépasser la température assignée du matériau ou du *composant* mesuré, et
- le coupe-circuit thermique et les fonctions et dispositifs de protection contre les surcharges ne doivent pas s'activer pendant l'essai.

5.2.3.11 Essai de la *liaison équipotentielle de protection* (*essai de type, essai individuel de série*)

5.2.3.11.1 Généralités

Comme cela est exigé en 4.4.4.2, chaque *partie accessible* conductrice à l'étude doit résister à l'*essai de type* de court-circuit*,* sauf si l'analyse indique que la capacité de tenue aux courts-circuits du chemin est adaptée ou que les résultats d'une combinaison sont représentatifs des résultats prévus de l'autre combinaison.

Chaque *partie accessible* conductrice à l'étude doit être soumise à l'essai séparément.

La *partie accessible* à l'étude doit être choisie parmi celles adjacentes aux circuits alimentés par le réseau en courant alternatif et être séparée de ces derniers par l'*isolation* principale uniquement.

L'essai de tenue au court-circuit de la *liaison équipotentielle de protection* du 5.2.4.4 doit être réalisé et le temps de déconnexion ne doit pas dépasser

- l'exigence de temps de déconnexion de l'IEC 60364-4-41:2005 et l'IEC 60364-4-41:2005/AMD1:2017, Tableau 41.1 (voir l'Annex Q), pour les équipements enfichables assignés à 63 A au maximum et les *équipements reliés en permanence* assignés à 32 A au maximum, et non destinés à être reliés à la distribution du bâtiment,
- 5 s pour les *systèmes* TN pour les *BDM/CDM/PDS* destinés à être directement connectés à la distribution du bâtiment, pour les équipements enfichables assignés à 63 A et pour les *équipements reliés en permanence* assignés à plus de 32 A, ou
- 1 s pour les *systèmes* TT pour les *BDM/CDM/PDS* destinés à être directement connectés à la distribution du bâtiment, pour les équipements enfichables assignés à 63 A et pour les *équipements reliés en permanence* assignés à plus de 32 A.

Pour les *équipements enfichables de type A* uniquement, l'essai de continuité de la *liaison équipotentielle de protection* du 5.2.3.11.2 doit être réalisé.

5.2.3.11.2 Essai de continuité de la liaison équipotentielle de protection (*essai de type, essai individuel de série*)

L'*essai individuel de série* de la *liaison équipotentielle de protection* doit être réalisé

- lorsqu'il est exigé en 4.4.4.2.2, 5.2.6.2, 5.2.4.4.4, 5.2.2.7.2 ou 5.2.3.11.1,
- lorsque le *PDS* est monté au niveau de l'emplacement de l'*installation*, ou
- lorsque la continuité de la *liaison équipotentielle de protection* est assurée par un seul dispositif (un seul conducteur ou un seul moyen de fixation, par exemple).

La valeur minimale du courant d'essai doit être de 10 A afin de permettre le mesurage ou le calcul de la résistance des moyens de *liaison équipotentielle de protection*.

NOTE Les courants plus importants utilisés pour l'essai de continuité augmentent l'exactitude du résultat d'essai, en particulier avec des valeurs d'impédance faibles, c'est-à-dire des sections plus importantes et/ou des longueurs de conducteur inférieures.

La valeur prévue de la résistance est le résultat d'un calcul ou d'une simulation prenant en considération la longueur, la section et le matériau des conducteurs de *liaison équipotentielle de protection* associés.

Le critère d'acceptation est tel que la résistance mesurée ne doit pas dépasser 110 % de la valeur prévue.

5.2.3.12 Essai à l'entrée du circuit (*essai de type)*

Comme cela est spécifié en 6.2.1, l'essai à l'entrée du circuit doit être réalisé pour déterminer le courant d'entrée maximal et la puissance d'entrée maximale dans le cadre d'un essai, d'un calcul ou d'une simulation dans les conditions les plus défavorables telles que, entre autres,

- caractéristiques assignées de tension d'entrée,
- caractéristiques de la source de puissance,
- puissance de sortie assignée,
- courant de sortie,
- caractéristiques d'allègement,
- mode de fonctionnement, et
- caractéristiques de commande de refroidissement.

L'essai doit être réalisé pour chaque *accès* de puissance d'entrée.

Ces valeurs doivent être spécifiées selon 6.2.

5.2.3.13 Essai du matériau pelliculé (*essai de type*)

5.2.3.13.1 Généralités

Le paragraphe 5.2.3.13 donne les exigences relatives aux essais des matériaux pelliculés selon 4.4.7.8.3.

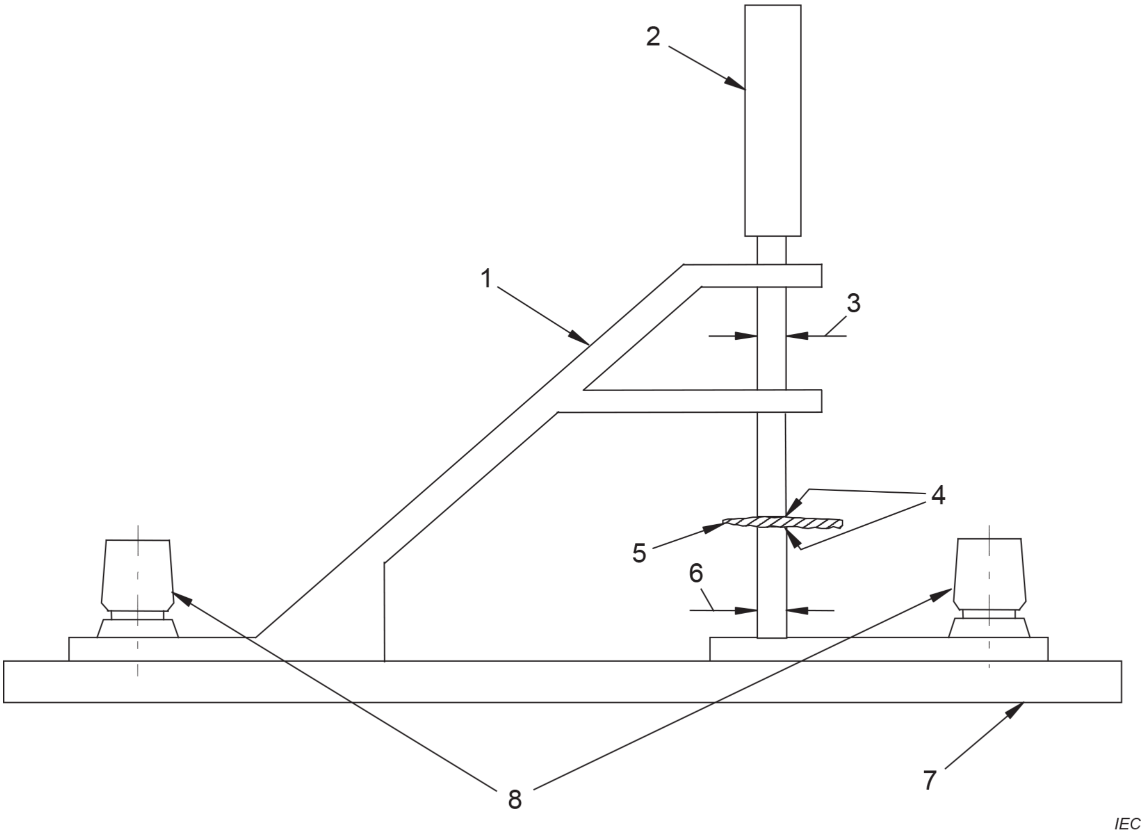
5.2.3.13.2 Procédure d'essai de matériau pelliculé séparable (*essai de type*)

Une couche de matériau séparable est placée dans l'instrument d'essai de rigidité diélectrique, comme cela est représenté à la Figure 16, et la tension d'essai satisfaisant aux exigences du Tableau 14 est appliquée.

L'essai est répété avec plusieurs couches, si cela est exigé dans le Tableau 14.

Afin d'éviter un *claquage électrique* autour des bords de la feuille de matériau isolant, l'échantillon à l'essai doit être suffisamment large pour que ses bords restent à distance des tiges d'essai verticales.

Cet essai peut être ignoré pour les matériaux non séparables composés d'au moins trois couches utilisées pour l'*isolation renforcée*, auquel cas l'essai au mandrin du 5.2.3.13.3 s'applique.



Légende

1 châssis métallique supportant la broche supérieure en position vertical et permettant son mouvement vers le haut et vers le bas

2 broche métallique pesant 100 g

3 Ø 5 mm ± 0,1

4 bords de la broche d'essai arrondis selon un rayon de 0,5 mm

5 éprouvette (matériau isolant) en essai

6 Ø 5 mm ± 0,1

7 support isolant

8 bornes pour la tension d'essai

Figure 16 – Instrument d'essai de rigidité diélectrique

5.2.3.13.3 Essai au mandrin (*essai de type*, *essai sur prélèvement*)

Les exigences d'essai de l'*isolation renforcée* en matériau non séparable constitué d'au moins trois couches de matériau isolant pelliculé sont spécifiées ci-dessous.

NOTE L'essai s'appuie sur l'IEC 61558-1:2017 et donne les mêmes résultats.

Trois échantillons d'essai sont utilisés, chacun d'eux étant composé d'au moins trois couches de matériau pelliculé non séparable formant une *isolation renforcée*.

Un échantillon est fixé au mandrin du montage d'essai de la Figure 17. La fixation doit être réalisée comme cela est indiqué à la Figure 18.

Dimensions en millimètres

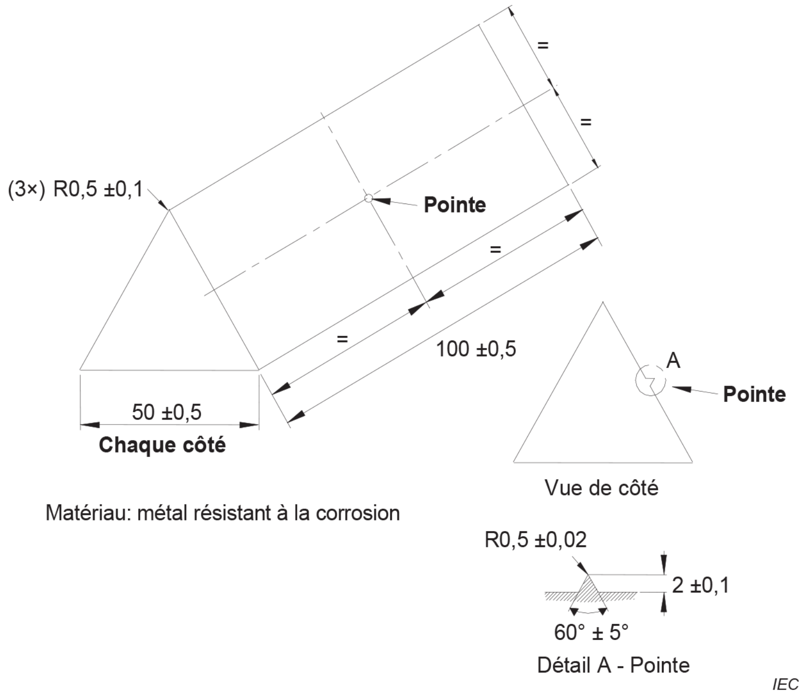
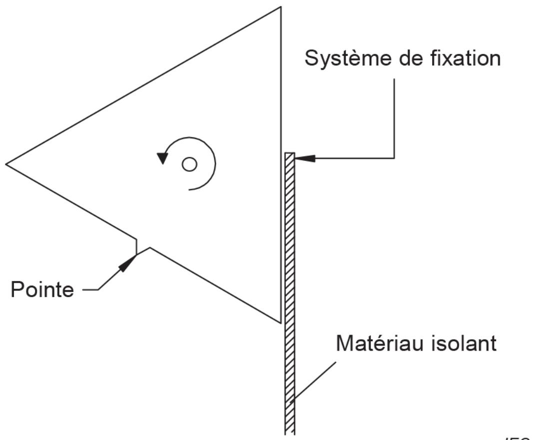
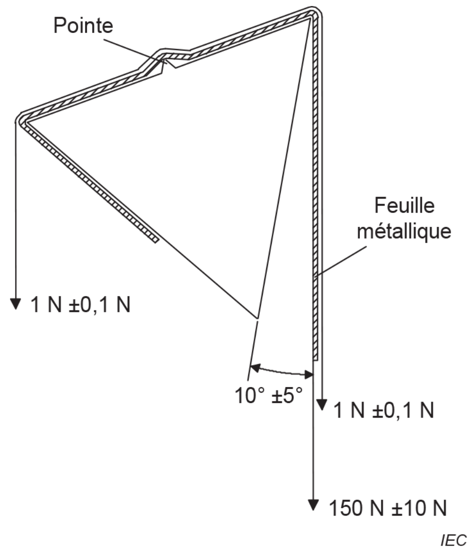


Figure 17 – Mandrin





La position finale du mandrin est pivotée de 230° ± 5° par rapport à la position initiale.

Figure 18 – Position initiale du mandrin

Figure 19 – Position finale du mandrin

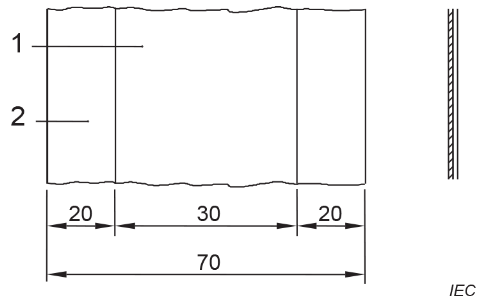
Une traction est appliquée à l'extrémité libre de l'échantillon à l'aide d'un dispositif d'attache. Le mandrin est pivoté

- de la position initiale (Figure 18) à la position finale (Figure 19) et inversement, et
- une seconde fois de la position initiale à la position finale.

Si un échantillon se brise pendant la rotation alors qu'il est fixé au mandrin ou au dispositif d'attache, il ne s'agit pas d'une défaillance. Si un échantillon se brise en un autre endroit, l'essai n'est pas satisfait.

Après l'essai ci-dessus, une feuille métallique de 0,035 mm ± 0,005 mm d'épaisseur et d'au moins 200 mm de longueur est placée sur la surface de l'échantillon, suspendu de chaque côté du mandrin (voir la Figure 19). La surface de la feuille en contact avec l'échantillon doit être conductrice, non oxydée, voire isolée. La feuille est positionnée de sorte que ses bords ne se trouvent pas à moins de 20 mm des bords de l'échantillon (voir la Figure 20). La feuille est ensuite maintenue par deux masses égales (une à chaque extrémité) à l'aide de dispositifs d'attache appropriés.

Dimensions en millimètres



Légende

1 feuille métallique

2 matériau isolant

Figure 20 – Position de la feuille métallique sur le matériau isolant

Le mandrin étant dans sa position finale, et dans les 60 s qui suivent le positionnement définitif, les essais de rigidité diélectrique sont réalisés entre le mandrin et la feuille métallique conformément à 4.4.7.10.

Pour l'*isolation renforcée*, la tension d'essai U_{essai} est égale à

- 100 % de la tension d'essai spécifiée pour l'essai de *tension de tenue aux chocs* du 4.4.7.10, et
- 150 % de la tension d'essai spécifiée pour l'essai de tension en courant alternatif ou en courant continu du 4.4.7.10.

Si la tension d'essai de U_{essai} est inférieure à 7,1 kV, l'essai de tension en courant alternatif ou en courant continu doit être remplacé par un essai de tension en courant alternatif de 5 kV en valeur efficace.

L'essai est répété sur les deux autres échantillons.

5.2.3.14 Procédure d'essai pour la détermination de la *tension de fonctionnement (essai de type)*

Lorsque cela est exigé en 4.4.7.1.2, la *tension de fonctionnement* doit être déterminée par calcul, par simulation ou par essai:

- *tension de fonctionnement* à l'intérieur des circuits;
- *tension de fonctionnement* par rapport aux *circuits adjacents*;
- *tension de fonctionnement* par rapport à la protection de mise à la terre.

Voir A.5.1, A.5.2, A.5.3, A.5.4 et A.5.5 pour les règles d'évaluation des formes d'onde de tension.

5.2.3.15 Essai de surveillance du *SPD* interne (*essai de type*)

Un *BDM/CDM* équipé d'un *SPD* interne avec un circuit de signalisation et de surveillance comme cela est décrit en 4.4.7.2.2 doit être soumis à cet essai. Chaque *SPD* d'un échantillon du *BDM/CDM* doit être à tour de rôle mis en court-circuit ou en circuit ouvert, si cette dernière condition est la plus défavorable. Le *BDM/CDM* doit être relié à sa source d'alimentation nominale.

Le *BDM/CDM* doit surveiller et détecter une défaillance du *SPD* et une indication d'alarme doit être fournie.

5.2.3.16 Préconditionnement du matériau (*essai de type*)

Lorsque cela est exigé en 4.4.7.8.4.2, 4.4.7.8.4.3 et 4.4.7.9, le préconditionnement suivant doit être réalisé sur le même échantillon dans l'ordre indiqué avant de procéder aux *essais de type*. Le nombre exigé d'échantillons est indiqué en 4.4.7.8.4.2, 4.4.7.8.4.3 ou 4.4.7.9 applicable:

1) essai de chaleur sèche du 5.2.6.3.2;
2) variation rapide de la température d'essai de -25 °C à +125 °C et 50 cycles conformément à l'IEC 60664-3:2016, 5.7.4 (essai Na de l'IEC 60068-2-14);
3) essai de chaleur humide du 5.2.6.3.4.

5.2.4 Essais de *fonctionnement anormal* et de défauts simulés

5.2.4.1 Généralités

La protection contre les risques de dangers thermiques, de dangers dus à l'énergie et de dangers de chocs électriques en cas de *condition anormale de fonctionnement* d'un *composant* pour un *BDM/CDM/PDS* combiné avec son *installation* doit être évaluée par:

a) des essais définis en 5.2.4;
b) pour les *BDM/CDM/PDS basse tension*, un calcul ou une simulation reposant sur les essais définis en 5.2.4.5 et 5.2.4.10 sur un modèle représentatif du *BDM/CDM/PDS*, où aucun dommage autre que l'ouverture de dispositifs de protection contre les *surintensités* ne s'est produit sur l'échantillon d'essai;

   NOTE 1 Un modèle représentatif est un *BDM/CDM/PDS* avec des éléments de puissance similaires (par exemple, *dispositifs à semiconducteurs de puissance*, fusibles, disjoncteurs, condensateurs, détection des *surintensités*, inductances d'entrée et inductances de sortie) et des topologies de circuit telles que le *PDS* à l'étude.

c) pour les *BDM/CDM/PDS haute tension*, un calcul ou une simulation reposant sur des essais d'éléments qui représentent de manière adéquate ceux utilisés dans le *BDM/CDM/PDS*. Les éléments, les essais et les conditions d'essais doivent être sélectionnés pour que les résultats des essais soient jugés suffisamment fiables pour être transférés (par exemple en échelonnant de la plus petite puissance à la plus grande) vers les *BDM/CDM/PDS* à l'étude; ou
d) pour un *PDS* personnalisé, l'analyse des risques et des dangers de l'application concernée et l'analyse des caractéristiques de la construction. Voir les exigences relatives aux informations de mise en service en 6.3.8.

   NOTE 2 Le *PDS* personnalisé repose sur les caractéristiques de construction de l'*installation* pour fournir une protection.

Sauf spécification contraire, avant de procéder à l'ensemble des essais de *fonctionnement anormal* et de défauts simulés, l'échantillon d'essai doit être monté, relié et utilisé comme décrit dans l'essai d'échauffement.

Les défauts simulés ou les *conditions anormales de fonctionnement* doivent être appliqués une seule fois. Les défauts qui sont la conséquence directe d'un défaut simulé ou de *conditions anormales de fonctionnement* sont considérés comme faisant partie intégrante de ce défaut simulé ou de cette *condition anormale de fonctionnement*.

Pour un *BDM/CDM/PDS* de *type ouvert*, le *BDM/CDM/PDS* doit être soumis à l'essai dans

1) une *enveloppe* solide non ventilée 1,5 fois dans chacune des dimensions linéaires individuelles du *BDM/CDM*,
2) une *enveloppe* grillagée 1,5 fois dans chacune des dimensions linéaires individuelles du *BDM/CDM*, ou
3) une *enveloppe* de dimension et de ventilation telles que décrites dans la documentation fournie avec le *BDM/CDM*.

Pour le marquage, voir 6.3.6.1.

Les *BDM/CDM/PDS* et la cage (s'il y a lieu) ou l'*enveloppe* grillagée doivent être mis à la terre conformément aux exigences du 4.4.4.2.2.

De l'étamine ou du coton hydrophile doit être disposé sur toutes les ouvertures, poignées, brides, joints et autres emplacements similaires sur les côtés extérieurs de l'enveloppe, et sur la cage grillagée (si elle est utilisée), d'une manière qui n'affecte pas de façon significative le refroidissement lorsque l'essai dure suffisamment longtemps pour obtenir un échauffement significatif.

Lorsque le *BDM/CDM/PDS* soumis à l'essai fait état, dans son manuel d'installation, d'exigences de moyens externes de protection contre les défauts, ces moyens spécifiques doivent être fournis pour l'essai.

Les essais individuels doivent être effectués jusqu'à ce que l'activation d'un dispositif ou d'un mécanisme (interne ou externe) de protection y mette fin, qu'une défaillance d'un *composant* se produise et interrompe la condition de défaut ou que la température se stabilise.

5.2.4.2 Tension, courant et fréquence d'alimentation

Les conditions d'essai du 5.1.5.3 s'appliquent.

La tension en circuit ouvert de l'alimentation doit être comprise entre 100 % et 105 % de la tension d'entrée assignée. La tension en circuit ouvert peut dépasser 105 % de la tension d'entrée assignée sur demande du fabricant.

Pour l'essai de court-circuit, l'alimentation doit être capable de fournir le *courant de court-circuit présumé* spécifié dans le Tableau 36 au point de raccordement du *BDM/CDM/PDS*.

Tableau 36 – *Courant de court-circuit présumé* pour l'essai par rapport au courant d'entrée assigné du *BDM/CDM/PDS*

Courant d'entrée assigné I_o du *BDM/CDM*	*Courant de court-circuit présumé*	Facteur de puissance (*BDM/CDM* prévu pour une entrée en courant alternatif uniquement)
A	kA	
$I_o \leq 16$	1	0,7 à 0,8
$16 < I_o \leq 63$	3	0,7 à 0,8
$63 < I_o \leq 125$	5	0,7 à 0,8
$125 < I_o \leq 315$	10	0,5 à 0,7
$315 < I_o \leq 630$	18	0,2 à 0,3
$630 < I_o \leq 1\,000$	30	0,2 à 0,3
$1\,000 < I_o \leq 1\,600$	42	0,2 à 0,3
$1\,600 < I_o$	$0{,}025 \times I_O + 2{,}5$ [a]	0,2 à 0,3

[a] Ou fait l'objet d'un accord entre l'utilisateur et le fabricant du *PDS*.

Les *courants de court-circuit présumés* du Tableau 36 sont considérés comme représentant la majorité des situations à basse tension que le *réseau* ou l'*alimentation non raccordée directement au réseau* peut fournir. Il s'agit également par défaut du *courant de court-circuit présumé maximal* auquel le *BDM/CDM/PDS* doit être connecté, sauf si le fabricant a spécifié une valeur plus élevée. Dans le cas où le fabricant spécifie une valeur *maximale de courant de court-circuit présumé* plus élevée, que celle fournie dans le Tableau 36, l'essai doit être réalisé en utilisant la valeur *maximale de courant de court-circuit présumé* la plus élevée et les paramètres d'essai doivent être corrects pour le niveau d'essai le plus élevé soumis à l'essai. Le facteur de puissance ne doit pas être supérieur au niveau spécifié dans le Tableau 36 pour le niveau de *courant de court-circuit présumé* suivant le plus élevé. Si le niveau maximal de *courant de court-circuit présumé* choisi dépasse 42 kA, le facteur de puissance ne doit pas dépasser 0,2 à 0,3; toutefois, un facteur de puissance inférieur peut être exigé en raison des circuits de laboratoires disponibles.

NOTE Les *BDM/CDM/PDS* étant protégés par des *dispositifs de protection contre les courts-circuits* installés en amont, il est important de comprendre que le *courant de court-circuit présumé* du Tableau 36 comme étant le *courant conditionnel de court-circuit* (I_{cc}) de l'IEC 62477-1:2022; 4.3.2.2.

Pour l'essai de défaillance de *composants*, l'alimentation doit être en mesure de délivrer un *courant de court-circuit présumé* du Tableau 36 ou les valeurs assignées du fabricant, selon la valeur la plus élevée. Toutefois, si l'analyse du 4.2 indique qu'une valeur inférieure du *courant de court-circuit présumé* d'alimentation donne le même résultat final, ce *courant de court-circuit présumé* d'alimentation inférieur est suffisant pour l'essai.

Dans les cas où le fabricant spécifie I_{cc} avec un courant de crête et une durée, un oscilloscope ou autre instrument adapté doit être utilisé pour mesurer le courant d'entrée de crête pendant l'essai et la durée de l'essai du 5.2.4.5, du 5.2.4.5.2, et du 5.2.4.10.

Dans les cas où le fabricant spécifie I_{cc} avec la tension assignée, le courant assigné, la valeur de coupure assignée, I_p et I^2t à I_{cc}, du dispositif de protection, le dispositif de protection utilisé pendant l'essai doit être représentatif de ces caractéristiques assignées.

5.2.4.3 Critères d'acceptation

Par suite des essais de *fonctionnement anormal* et de défaut simulé, le *BDM/CDM/PDS* doit satisfaire aux conditions suivantes:

a) il ne doit y avoir aucune émission de flamme, de particules brûlantes ou de métal fondu;
b) l'indicateur en étamine ou en coton hydrophile ne doit pas s'être enflammé;
c) la connexion à la terre et la *liaison équipotentielle de protection* du *BDM/CDM/PDS* ne doivent pas être ouvertes;
d) les *portes* et les *capots* doivent rester en place;
e) les circuits *CTD As accessibles* ne doivent pas présenter de tensions supérieures aux tensions temporelles du Tableau 2, de la Figure 2, de la Figure 3 ou de la Figure 4 telles qu'applicables pendant l'essai;
f) pendant et après l'essai, les *parties actives dangereuses* ne doivent pas devenir accessibles;
g) les conducteurs d'entrée et de sortie de *réseau* et *d'alimentation non raccordée directement au réseau* ne doivent pas se détacher de leur connecteur de borne;
h) aucune partie ne doit être éjectée.

Le *BDM/CDM/PDS* doit satisfaire à l'essai de tension en courant alternatif ou en courant continu qui suit les essais de *fonctionnement anormal* du 5.2.4.12 et du 5.2.4.13. Un seul échantillon peut être utilisé pour plusieurs essais, auquel cas l'essai de tension en courant alternatif ou en courant continu peut être réalisé après chaque essai ou après le dernier essai de la séquence.

Il n'est pas nécessaire que les *BDM/CDM/PDS* fonctionnent après les essais et il est possible que l'*enveloppe* puisse se déformer.

Il est admis que la protection contre les *surintensités*, partie intégrante des *BDM/CDM/PDS* ou devant être utilisée avec ledit *BDM/CDM/PDS*, puisse s'ouvrir.

De plus, à l'issue de

- l'essai de court-circuit entre phases du 5.2.4.5.2,
- l'essai de court-circuit phase-terre du 5.2.4.5.3, et
- l'essai de défaillance de *composants* du 5.2.4.10,

le *BDM/CDM/PDS* doit fonctionner jusqu'à ce que l'un ou plusieurs des résultats finaux suivants soient obtenus:

i) le fonctionnement du *circuit électronique de protection contre les courts-circuits en sortie de puissance*;
j) l'ouverture d'un *dispositif de protection contre les courts-circuits* (*SCPD*);
k) une température constante atteinte après une durée minimale de 10 min.

5.2.4.4 Essai de tenue au court-circuit de la *liaison équipotentielle de protection (essai de type)*

5.2.4.4.1 Généralités

Comme cela est exigé par 5.2.3.11.1, un essai de court-circuit doit être réalisé pour assurer que la *liaison équipotentielle de protection* est en mesure de résister au *courant de court-circuit présumé* auquel elle peut être soumise dans des *conditions de premier défaut*.

5.2.4.4.2 Conditions d'essai

Sauf si l'analyse de circuit du 4.2 a abouti à un autre résultat, la condition représentative la plus défavorable consiste à provoquer un court-circuit entre l'un des principaux *accès d'alimentation* et la *partie accessible* conductrice à l'étude.

Le *BDM/CDM/PDS* en essai doit être alimenté et *l'accès de puissance* de sortie doit fonctionner comme prévu en 5.2.4.1 avant la fermeture des dispositifs de commutation qui appliquent le court-circuit.

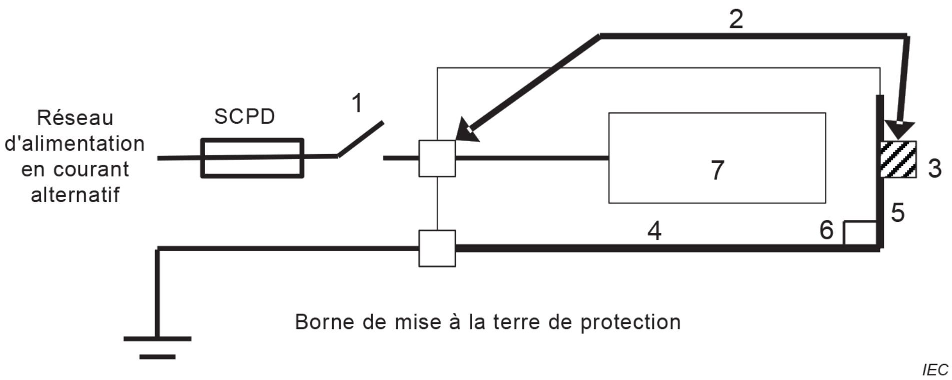
La tension et le courant d'alimentation de la source doivent être tels que le courant obtenu passant par la *liaison équipotentielle de protection* (y compris les câbles et le dispositif de coupure) soit égal au *courant de court-circuit présumé*.

L'essai de court-circuit de la *liaison équipotentielle de protection* doit être réalisé avec le *BDM/CDM/PDS* fonctionnant à charge faible.

Un nouvel échantillon peut être utilisé pour chaque essai de court-circuit.

5.2.4.4.3 Méthode d'essai de court-circuit de la *liaison équipotentielle de protection*

Le courant d'essai est appliqué en connectant la *partie accessible* conductrice à l'étude à l'un des conducteurs du circuit source d'essai par l'intermédiaire d'un dispositif de commutation qui ne doit pas limiter le courant de court-circuit. Le commutateur doit être placé de sorte que la source soit court-circuitée par l'intermédiaire de la *partie accessible* conductrice et que son chemin de *liaison équipotentielle de protection* retourne à la borne de *mise à la terre de protection* du circuit source à l'étude. Voir la Figure 21.



Légende	
1 commutateur de mise sous tension	5 *partie accessible* conductrice
2 fil pour simuler le défaut	6 plusieurs liaisons de fixation
3 point de défaut de connexion	7 *partie active dangereuse*
4 *liaison équipotentielle de protection* interne	

Figure 21 – Montage d'essai de la *liaison équipotentielle de protection*

5.2.4.4.4 Critères d'acceptation

À l'issue de l'essai, outre les critères d'acceptation du 5.2.4.3, les moyens de *liaison équipotentielle de protection* en essai ne doivent pas être endommagés, et les temps de déconnexion du 5.2.3.11.1 ne doivent pas être dépassés.

La conformité doit être vérifiée par l'*inspection visuelle* du 5.2.1, et, si nécessaire, par l'essai de continuité de *liaison équipotentielle de protection* du 5.2.3.11.2.

5.2.4.5 Essai de court-circuit en sortie (*essai de type*)

5.2.4.5.1 Conditions de charge

Lorsque cela est exigé par 4.3.2, l'essai de court-circuit en sortie doit être réalisé à pleine charge, à faible charge ou à vide, la condition retenue étant celle qui génère la condition la plus sévère.

5.2.4.5.2 Essai de court-circuit entre les bornes de phase de l'*accès* de puissance de sortie (*essai de type*)

Comme cela est exigé en 4.3.1, les *accès* de puissance d'entrée du *BDM/CDM/PDS* en essai doivent être équipés de conducteurs présentant une section maximale admise par les instructions d'installation pour les *accès* de puissance d'entrée.

Les *accès* de puissance de sortie doivent être équipés de conducteurs présentant une section maximale admise par les instructions d'installation pour les *accès* de puissance de sortie. La longueur de la boucle (avant et arrière) doit être d'environ 2 m, à moins que la dimension du *BDM/CDM/PDS* n'exige une longueur supérieure, auquel cas la longueur doit être aussi courte que possible pour réaliser l'essai.

Toutes les bornes de phase de chaque *accès* de puissance de sortie soumis à l'essai doivent être connectées ensemble simultanément, à l'aide d'un dispositif de coupure approprié.

NOTE Les bornes connectées à la liaison à courant continu servent aux essais du 5.2.4.5.2 et du 5.2.4.5.3, en tant que phases.

Le *BDM/CDM/PDS* en essai doit être alimenté et les accès de puissance de sortie doivent fonctionner comme prévu avant la fermeture des dispositifs de commutation qui appliquent le court-circuit, sauf si la mise sous tension du *BDM/CDM/PDS* avec le court-circuit déjà appliqué est plus sévère.

Les essais doivent inclure des essais individuels de chaque *accès* de puissance de sortie dans lesquels des combinaisons d'au moins deux bornes, terre exclue, sur chaque accès de puissance de sortie individuel font l'objet d'essais de court-circuit sur ces bornes. Une analyse peut être utilisée pour réduire le nombre d'essais s'il est démontré que les résultats d'une combinaison sont représentatifs des résultats prévus de l'autre combinaison.

Un nouvel échantillon peut être utilisé pour chaque essai de court-circuit.

De plus, cet essai permet de déterminer les caractéristiques assignées du *courant de court-circuit en sortie* de l'*accès* de puissance de sortie à l'étude, conformément à 4.3.2.3 lorsque la protection interne contre les courts-circuits n'est pas fournie.

Si les instructions d'installation d'un *BDM/CDM* de *type ouvert* spécifient un SCPD externe pour un *accès* de puissance de sortie, l'essai doit être réalisé sans le SCPD dans le circuit de sortie, sauf si les instructions du fabricant précisent que le SCPD doit être fourni et qu'il doit se trouver dans la même *enveloppe* finale que le *BDM/CDM*.

Pour la conformité à 4.3.2.3, un oscilloscope ou autre instrument adapté doit être utilisé pour mesurer le courant de sortie de crête pendant l'essai et mesurer ou calculer la valeur efficace du courant de sortie.

Le courant de crête et les valeurs efficaces les plus élevées du courant sont mesurés ou calculés sur la période qui suit, et doivent être inclus dans la documentation, voir 6.2:

a) pour les signaux en courant alternatif, trois cycles de la fréquence nominale en courant alternatif pour l'*accès* de puissance de sortie à l'étude, auquel cas la valeur doit être indiquée en tant que valeur efficace sur 3 cycles;
b) pour tous les signaux, la durée du court-circuit entre le moment auquel il est appliqué et le moment auquel le courant de court-circuit est interrompu par un dispositif ou autre mécanisme de protection, auquel cas la valeur indiquée doit inclure la valeur efficace et la période en secondes;
c) pour les essais de court-circuit qui donnent une valeur non nulle continue, la valeur efficace en régime permanent, auquel cas la valeur doit être indiquée en tant que valeur efficace continue.

5.2.4.5.3 Essai de court-circuit entre les bornes de phase des *accès* de puissance de sortie et la terre (*essai de type*)

Pour les *BDM/CDM/PDS* destinés à être reliés à des *systèmes* TN ou des *systèmes* TT, la condition de défaut entre la phase et la mise à la terre de protection doit être évaluée pour chaque phase, l'une après l'autre, comme un court-circuit de la mise à la terre de protection. Un court-circuit entre les bornes de phase des *accès* de puissance de sortie ne s'applique pas aux *BDM/CDM/PDS* destinés uniquement à être reliés à des *systèmes* IT.

Il est admis de n'opérer qu'un essai par sortie si une symétrie de phase peut être démontrée et si la phase choisie pour être soumise à l'essai représente le cas le plus grave.

Voir la Figure 22, la Figure 23 et la Figure 24 pour des exemples.

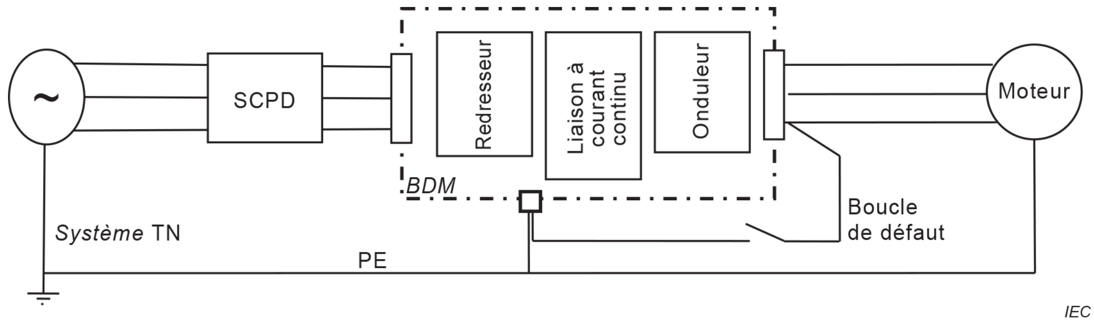


Figure 22 – Exemple d'essai de court-circuit entre l'accès de puissance du moteur du *BDM/CDM* et la *terre de protection* (moteur mis à la terre séparément)

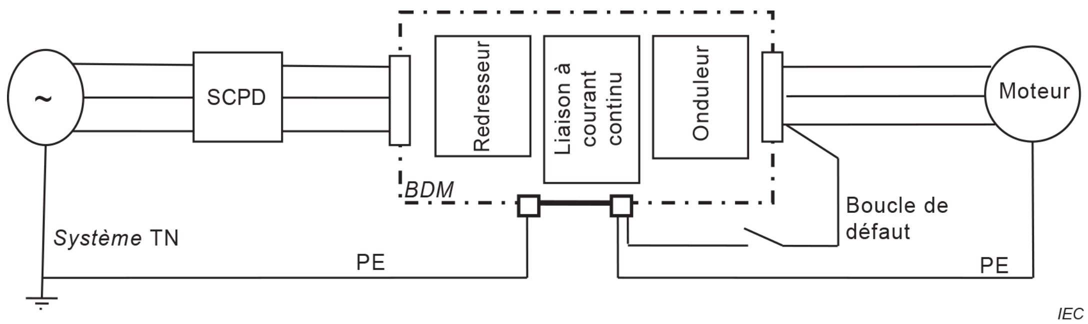


Figure 23 – Exemple d'essai de court-circuit entre l'accès de puissance du moteur du *BDM/CDM* et la *terre de protection* (moteur mis à la terre par l'intermédiaire du *BDM/CDM*)

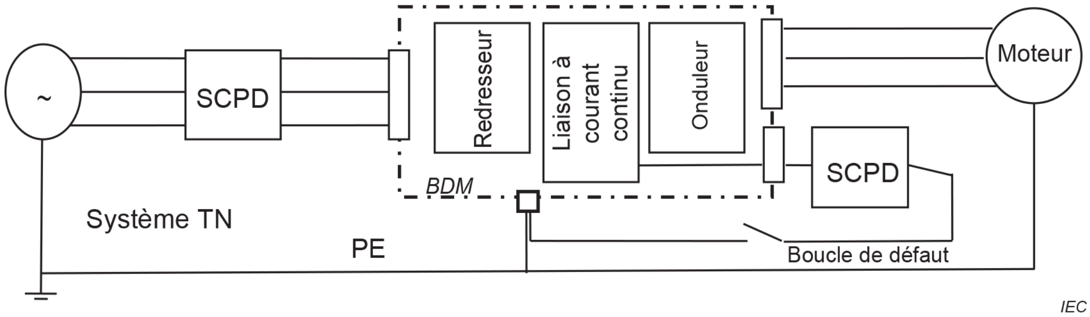


Figure 24 – Exemple d'essai de court-circuit entre l'accès de puissance de la liaison en courant continu du *BDM/CDM* et la *terre de protection*

5.2.4.6 Essai de *protection électronique contre les surcharges du moteur* (*essai de type*)

5.2.4.6.1 Exigences générales

Lorsque cela est exigé en 4.3.5, cet essai doit démontrer, sur un échantillon de modèle représentatif, que la *protection électronique contre les surcharges du moteur* fonctionne dans les limites spécifiées.

Les séries de *BDM/CDM/PDS* avec *protection électronique contre les surcharges du moteur* intégrée doivent se conformer aux essais visés en 5.2.4.6.4.

Les séries de *BDM/CDM/PDS* avec *protection électronique contre les surcharges du moteur* intégrée qui a une *rétention de mémoire thermique* doivent avoir un échantillon du modèle représentatif utilisé conforme aux essais visés en 5.2.4.6.4, 5.2.4.6.5 et 5.2.4.6.6.

Les séries de *BDM/CDM/PDS* avec *protection électronique contre les surcharges du moteur* intégrée qui est sensible à la vitesse doivent avoir un échantillon du modèle représentatif utilisé conforme aux essais visés en 5.2.4.6.4 et 5.2.4.6.7.

5.2.4.6.2 Montage d'essai

Avant de procéder aux essais, l'échantillon d'essai doit être monté, relié et utilisé comme décrit dans l'essai d'échauffement, puis soumis aux conditions de surcharge.

Le moteur peut être simulé par une charge électrique composée d'une résistance et/ou d'une réactance, de sorte que la charge transporte tout le courant en valeur efficace exigé au niveau de l'*accès* de puissance du moteur du *BDM/CDM*.

5.2.4.6.3 Critères d’acceptation

Le *BDM/CDM/PDS* doit être opérationnel après les essais et doit satisfaire à chaque exigence des essais applicables du 5.2.4.6.4, du 5.2.4.6.5, du 5.2.4.6.6 et du 5.2.4.6.7.

5.2.4.6.4 Essai de *protection électronique contre les surcharges du moteur* (*essai de type*)

À des fins de vérification de la fonctionnalité de la *protection électronique contre les surcharges du moteur*, l'essai doit être réalisé à tout courant permettant de vérifier les conditions de déclenchement en cas de surcharge conformément au Tableau 37.

Les *BDM/CDM* avec des niveaux de protection contre les surcharges fixés doivent être conformes au Tableau 37 dans toutes les configurations possibles. Les *BDM/CDM* avec des niveaux de protection contre les surcharges réglables doivent être conformes au Tableau 37 dans les réglages les plus bas et les plus élevés.

La *protection électronique contre les surcharges du moteur* du modèle représentatif doit *se déclencher* à tout point inférieur aux limites du Tableau 37.

Tableau 37 – Délai de déclenchement maximal pour l'essai de la *protection électronique contre les surcharges du moteur*

Multiple du courant de réglage	Délai de déclenchement maximal
7,2	20 s
1,5	8 min
1,2	2 h
NOTE 1 Le courant de réglage est défini comme étant le courant assigné du moteur conformément à sa plaque signalétique, qui a vocation à être protégée. NOTE 2 Le Tableau 37 couvre les exigences minimales pour les relais de surcharge électroniques de classe 20 conformes à l'IEC 60947-4-1:2018, 8.2.1.5.1.1.	

Si le *BDM/CDM* se déclenche dans un délai inférieur ou égal au délai de déclenchement maximal pour un multiple du courant de réglage à un courant d'essai inférieur au courant exigé par le multiple du courant de réglage, le *BDM/CDM* est considéré comme satisfaisant à cette ligne du Tableau 37.

Les *BDM/CDM* comportant une fonction de limitation de courant (voir 4.3.6) doivent être soumis à l'essai au multiple des courants de réglage du Tableau 37 inférieur au point de fonctionnement de limitation de courant. La charge doit ensuite être réglée sur le point de fonctionnement de la fonction de limitation de courant. Le *BDM/CDM* doit se *déclencher* dans le délai établi par la courbe de la Figure 25 pour le courant auquel la fonction de limitation de courant opère. Si le point de fonctionnement de limitation de courant est inférieur à 1,2 fois le courant, le *BDM/CDM* doit se *déclencher* lorsqu'il est soumis à l'essai au point de fonctionnement de limitation de courant. Un multiple des courants de réglage du Tableau 37 supérieur au point de fonctionnement de limitation de courant n'exige aucune vérification n.

Par exemple, un BDM/CDM dont une fonction de limitation de courant opère à un multiple du courant de réglage de 4,0 doit être soumis à l'essai aux multiples 1,2, 1,5 et 4,0 du courant. Il n'est pas exigé de soumettre à l'essai le multiple 7,2 du courant de réglage.

Les *BBDM/CDM* adaptés au contrôle d'une gamme de moteurs doivent être réglés pour les caractéristiques assignées les plus petites du moteur dont les instructions d'installation du *BDM/CDM* spécifient que la protection contre les surcharges du moteur a été fournie.

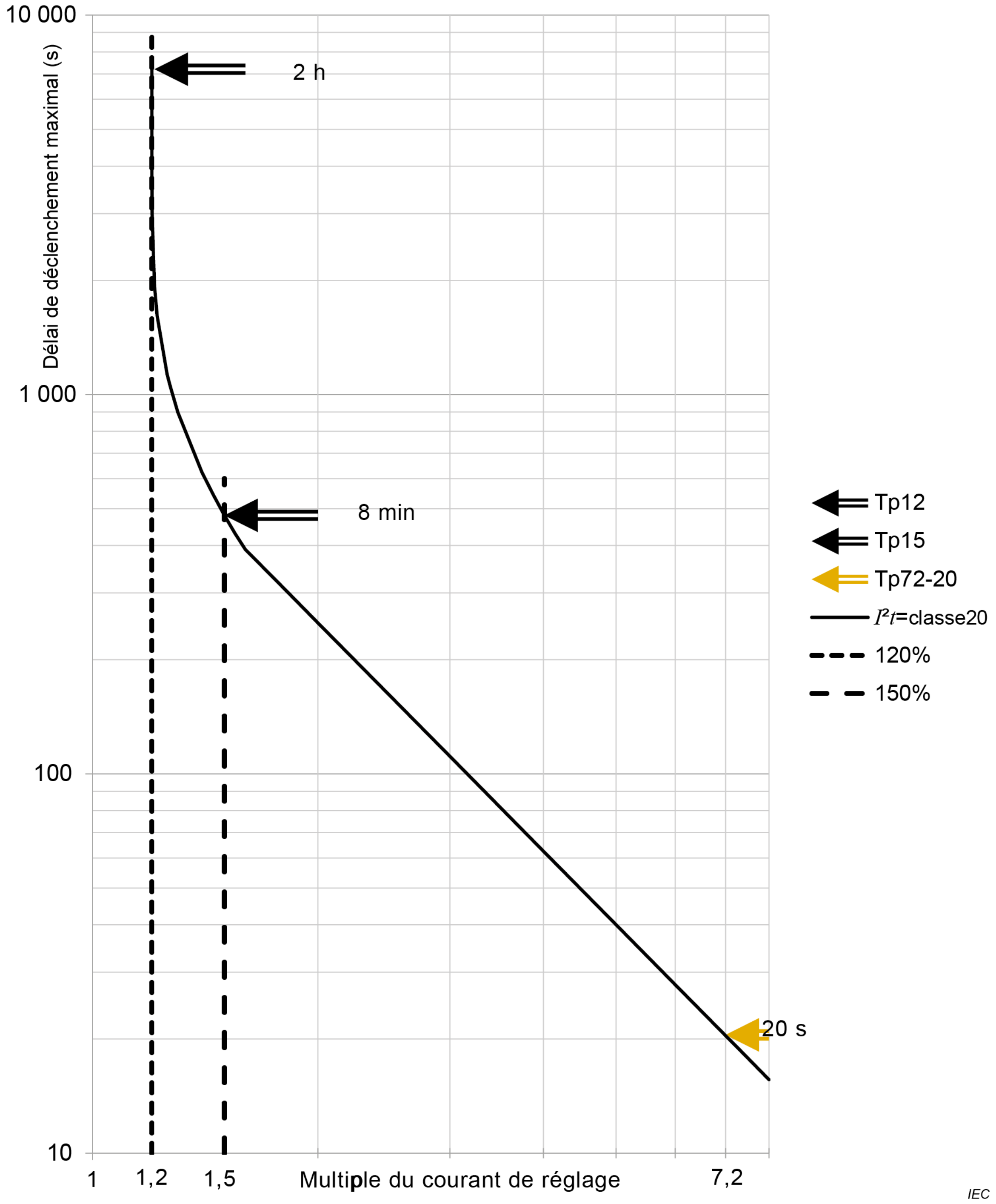


Figure 25 – Valeurs interpolées du Tableau 37

À la Figure 25, la relation entre le délai de déclenchement t et le multiple des limites x de courant de réglage

- avec x inférieur ou égal à 1,6 est donnée par $t = -470 \times \ln(1 - 1{,}2^2/x^2)$ à partir d'une réponse d'approximation de premier ordre avec une constante de temps de 470 s et un déclenchement à $1{,}2^2$, et
- avec x supérieur à 1,6 est donnée par une constante x^2t =1 000 à partir d'une réponse d'approximation adiabatique.

5.2.4.6.5 Essai de *déclenchement électronique de la rétention de mémoire thermique* du moteur (*essai de type*)

L'objet de cet essai est de vérifier que la fonctionnalité de *protection électronique contre les surcharges du moteur* évaluée selon 5.2.4.6.4 maintient la *mémoire thermique* lorsque le *BDM/CDM* est redémarré après un *déclenchement*. L'essai doit être réalisé dans les conditions spécifiées en 5.2.4.6.5.

L'essai est réalisé de la manière suivante:

a) la *mémoire thermique* du *BDM/CDM* est réinitialisée;
b) le *BDM/CDM* doit fonctionner à tout multiple du courant de réglage conformément au Tableau 37 jusqu'à ce que la protection contre les surcharges *déclenche* le *BDM/CDM*;la durée entre le début de la condition de surcharge et le déclenchement correspond à la première durée écoulée;
c) l'essai doit être relancé immédiatement sans débrancher l'alimentation et dans les mêmes conditions de surcharge, dans un délai plus court que la première durée écoulée;
d) le *BDM/CDM* doit fonctionner jusqu'à ce que la protection contre les surcharges *déclenche* de nouveau le *BDM/CDM*;
e) la durée entre le début de la deuxième condition de surcharge et le déclenchement correspond à la deuxième durée écoulée.

La conformité est vérifiée lorsque la deuxième durée écoulée jusqu'au déclenchement est inférieure à la première.

Pour les exigences d'informations, voir 6.3.9.7.

5.2.4.6.6 Essai de perte de *rétention de mémoire thermique* électronique du moteur (*essai de type*)

L'objet de cet essai est de vérifier que la *protection électronique contre les surcharges du moteur* évaluée selon 5.2.4.6.4 maintient la *mémoire thermique* lorsque le *BDM/CDM* est redémarré après un *déclenchement* et une perte de tension d'alimentation. L'essai doit être réalisé dans les conditions spécifiées en 5.2.4.6.6.

L'essai est réalisé de la manière suivante:

a) la *mémoire thermique* du *BDM/CDM* est réinitialisée;
b) le *BDM/CDM* doit fonctionner à tout multiple du courant de réglage conformément au Tableau 37 jusqu'à ce que la protection contre les surcharges *déclenche* le *BDM/CDM*;
c) la durée entre le début de la condition de surcharge et le déclenchement correspond à la première durée écoulée;
d) toutes les alimentations doivent être débranchées du *BDM/CDM*;
e) attendre que tous les circuits des fonctions de commande cessent de fonctionner, à l'exception des circuits alimentés par une source interne telle qu'une batterie;
f) immédiatement après, toutes les alimentations doivent être rétablies sur le *BDM/CDM*;
g) l'essai doit être immédiatement relancé dans les mêmes conditions de surcharge dans un délai plus court que la première durée écoulée;
h) le *BDM/CDM* doit fonctionner jusqu'à ce que la protection contre les surcharges *déclenche* de nouveau le *BDM/CDM*;
i) la durée entre le début de la deuxième condition de surcharge et le déclenchement correspond à la deuxième durée écoulée.

La conformité est vérifiée lorsque la deuxième durée écoulée jusqu'au déclenchement est inférieure à la première.

L'étape e) peut être ignorée si le fabricant démontre que les données stockées par la *mémoire thermique* sont retenues suffisamment longtemps pour assurer la protection du moteur.

Pour les exigences d'informations, voir 6.3.9.7.2.

5.2.4.6.7 Essai de sensibilité thermique à la vitesse du moteur électronique (*essai de type*)

L'objet de cet essai est de vérifier que la fonctionnalité de la *protection électronique contre les surcharges du moteur* évaluée selon 5.2.4.6.4 maintient la *mémoire thermique* en cas de régime réduit du moteur. L'essai doit être réalisé dans les conditions spécifiées en 5.2.4.6.7.

NOTE Les moteurs avec une turbine de ventilateur montée sur l'arbre présentent un refroidissement réduit à bas régime.

L'essai est réalisé de la manière suivante:

a) la *mémoire thermique* du *BDM/CDM* est réinitialisée;
b) le *BDM/CDM* doit fonctionner à 40 % de la fréquence de sortie assignée (pour les sorties en courant alternatif) ou de la tension de sortie assignée (pour les sorties en courant continu) et à tout multiple du courant de réglage conformément au Tableau 37 jusqu'à ce que la protection contre les surcharges déclenche le *BDM/CDM*;
c) la durée entre le début de la condition de surcharge et le déclenchement correspond à la première durée écoulée;
d) la *mémoire thermique* du *BDM/CDM* est réinitialisée;
e) le *BDM/CDM* doit être immédiatement redémarré à 20 % de la fréquence de sortie assignée (pour les sorties en courant alternatif) ou de la tension de sortie assignée (pour les sorties en courant continu), dans les mêmes conditions de surcharge;
f) le *BDM/CDM* doit fonctionner jusqu'à ce que la protection contre les surcharges *déclenche* de nouveau le *BDM/CDM*;
g) la durée entre le début de la deuxième condition de surcharge et le déclenchement correspond à la deuxième durée écoulée.

La conformité est vérifiée lorsque la deuxième durée écoulée jusqu'au déclenchement est inférieure à la première.

Si l'essai du *BDM/CDM* n'est pas possible avec les valeurs ci-dessus, en raison des caractéristiques du moteur, des valeurs plus pratiques peuvent être choisies pour la fréquence ou la tension.

Pour les PDS où le moteur et le BDM/CDM sont connus, les limites des paramètres d'essai ci-dessus peuvent être choisies en fonction des caractéristiques du moteur.

Pour les exigences d'informations, voir 6.3.9.7.2.

5.2.4.7 Essai d'évaluation de la fonctionnalité du circuit (*essai de type, essai individuel de série, essai sur prélèvement*)

L'évaluation de la fonctionnalité du circuit est exigée pour vérifier le matériel et les logiciels utilisés pour la conformité aux *essais de type* exigés par

a) la *protection contre les courts-circuits en sortie de puissance* selon 5.2.4.5, et
b) la *protection électronique contre les surcharges du moteur* selon 5.2.4.6.

NOTE La vérification de la fonctionnalité n'exige pas de réaliser chaque étape du 5.2.4.5 et du 5.2.4.6, mais seulement de vérifier la disponibilité de la protection.

Avant d'être expédiées depuis l'usine de fabrication, toutes les *protections contre les courts-circuits en sortie de puissance* et les *protections électroniques contre les surcharges du moteur* doivent être soumises à une procédure impliquant

c) la détection précoce des défauts de fabrication dans le cadre d'un *essai sur prélèvement* ou d'un *essai individuel de série*, et

d) la vérification de la fonctionnalité dans le cadre d'un *essai individuel de série*.

Cette procédure de détection et de vérification peut inclure l'une des approches suivantes:

e) un déverminage des *composants* entrants;

f) une méthode de rodage dont les conditions (telles que la durée, la température et autres conditions similaires) varient;

g) un essai de diagnostic, qui peut être accompli en fournissant des signaux pour le logiciel et/ou le matériel.

5.2.4.8 Essai de limitation de courant (*essai de type*)

Les *BDM/CDM/PDS* intégrant une commande de limitation de courant selon 4.6.1 doivent être utilisés en augmentant la charge, de manière à atteindre le mode de limitation de courant. Si la commande de limitation de courant est réglable, elle doit l'être en fonction du résultat obtenu dans les conditions les plus sévères.

5.2.4.9 Essai de surcharge en sortie (*essai de type*)

Lorsque cela est exigé par 4.6.1, l'essai de surcharge de sortie doit être réalisé après avoir utilisé le *BDM/CDM/PDS* à pleine charge tant que les températures de fonctionnement normales n'ont pas été atteintes. À l'exception des sorties satisfaisant aux exigences de source de puissance limitée du 4.5.3, chaque *accès* de puissance de sortie du *BDM/CDM/PDS* et chaque section d'une sortie à prises doit être surchargé l'un après l'autre. Les autres *accès* de puissance de sortie sont chargés ou non, la condition de charge en condition normale de fonctionnement la moins favorable étant retenue.

Le courant d'essai de surcharge de sortie doit être obtenu en connectant une charge variable à l'accès de puissance de sortie. La charge est réglée aussi rapidement que possible, puis de nouveau réglée, le cas échéant, après 1 min afin de maintenir la surcharge applicable. Aucun autre réglage supplémentaire n'est alors admis.

Le courant d'essai de surcharge de sortie doit satisfaire à ce qui suit:

a) pour les *BDM/CDM/PDS* dont la protection contre les *surintensités* est assurée par un dispositif ou circuit sensible au courant, le courant d'essai de surcharge est égal au courant maximal que le *dispositif de protection contre les surintensités* est en masure de passer pendant 1 h. Avant l'essai, le *dispositif de protection contre les surintensités* est rendu inopérant ou est remplacé par une liaison d'impédance négligeable;

b) pour les *BDM/CDM/PDS* dont la tension de sortie s'écroule lorsqu'un courant de surcharge spécifié est atteint, la surcharge est lentement augmentée jusqu'à la puissance de sortie maximale avant le point d'écroulement de la tension de sortie.

Dans tous les autres cas, la charge est la sortie de puissance maximale qui peut être obtenue depuis l'*accès* de puissance de sortie.

5.2.4.10 Essai de défaillance de *composants* (*essai de type*)

5.2.4.10.1 Conditions de charge

La défaillance d'un *composant*, identifiée par suite de l'analyse des circuits du 4.2, doit être soumise à l'essai avec le *BDM/CDM/PDS* à pleine charge ou faible charge, la condition retenue étant celle qui génère la condition la plus sévère.

5.2.4.10.2 Application d'un court-circuit ou d'un circuit ouvert

Le court-circuit doit être appliqué avec un câble présentant une section appropriée pour le courant qui va être amené à circuler dans le *composant* lors du défaut pendant la durée de l'essai sans fusion, mais pas moins de 2,5 mm^2. La longueur de la boucle doit être aussi courte que possible pour réaliser l'essai. Les courts-circuits et circuits ouverts sont appliqués à l'aide d'un dispositif de coupure en mesure de transporter le courant de défaut pendant la durée de l'essai.

Chaque *composant* identifié doit faire l'objet

- d'un seul essai de défaillance de *composants*, sauf si les modes de défaillance de court-circuit et de circuit ouvert sont probables dans ledit *composant*, et
- aux essais pertinents de défaillance de *composants* présentés dans l'évaluation du 4.2.

5.2.4.10.3 Séquence des essais

Pour l'essai de défaillance de *composants*, les *composants* identifiés doivent être mis en court-circuit ou en circuit ouvert, la condition retenue étant celle qui génère le danger le plus important, l'un après l'autre. Si l'analyse du 4.2 ne permet pas de définir la condition qui génère le cas le plus défavorable, l'essai de court-circuit et l'essai de circuit ouvert sont tous deux exigés.

Voir 5.2.4.3 pour les critères d'acceptation.

5.2.4.11 Essai de court-circuit des cartes de circuit imprimé (*essai de type*)

Sur les cartes de circuit imprimé et les *composants* montés sur carte de circuit imprimé, l'*isolation fonctionnelle* peut être assurée par des *distances d'isolement* et des *lignes de fuite* inférieures à celles spécifiées en 4.4.7.4 et 4.4.7.5. Les *distances d'isolement* et *lignes de fuite* réduites doivent être court-circuitées une par une, sur des échantillons représentatifs, et le court-circuit doit être maintenu jusqu'à ce qu'aucun autre dommage ne survienne.

Voir 5.2.4.3 pour les critères d'acceptation.

5.2.4.12 Essai de perte de phase (*essai de type*)

Un *BDM/CDM/PDS* multiphase doit fonctionner avec chacune des phases (y compris le neutre, s'il est utilisé) déconnectées à tour de rôle à l'entrée. L'essai doit être réalisé en déconnectant une phase avec le *BDM/CDM/PDS* fonctionnant à sa charge normale maximale. Il doit être répété en mettant d'abord sous tension le *BDM/CDM/PDS* avec un fil débranché.

S'il peut être résolument déterminé que la déconnexion d'une seule phase donne lieu à une condition plus sévère (la déconnexion de la phase avec le dispositif de protection qui risque le moins de répondre à la perte de phase, par exemple), l'essai peut être réalisé en déconnectant uniquement ladite phase au lieu de chaque phase à tour de rôle.

L'essai doit être effectué jusqu'à ce qu'un mécanisme de protection y mette fin, qu'une défaillance d'un *composant* survienne ou que la température se stabilise.

Pour les *BDM/CDM/PDS* dont le courant d'entrée assigné est supérieur à 500 A, la conformité peut être démontrée par simulation.

NOTE Si des fusibles sont utilisés, une tension peut demeurer au niveau de la phase ouverte, provoquée par les impédances internes à l'intérieur du *BDM/CDM/PDS* connecté entre les phases.

5.2.4.13 Essai de défaillance du système de refroidissement (*essai de type*)

5.2.4.13.1 Généralités et critères d'acceptation

Pour un *BDM/CDM/PDS* associant plusieurs mécanismes de refroidissement, tous les essais appropriés doivent être effectués. Il n’est pas nécessaire d’effectuer les essais simultanément.

L'essai doit se poursuivre tant que

- la température n'est pas stabilisée, auquel cas les limites de température des *parties accessibles* du 4.6.5.3 s'appliquent, ou
- un mécanisme de protection n'y a pas mis fin ou qu'une défaillance du *composant* ne s'est pas produite, auquel cas les limites de température des *parties accessibles* du 4.6.5.3 peuvent être dépassées de 5 °C au maximum.

Lorsque cette limitation de la température s’avère impossible, les documents d'utilisation doivent contenir un avertissement selon 6.4.4.

NOTE Une augmentation de 5 °C de la température par rapport aux limites en régime établi reflète la diffusion du seuil de brûlure indiqué dans le Guide IEC 117.

5.2.4.13.2 Essai de moteur de ventilateur inopérant (*essai de type*)

Un *BDM/CDM/PDS* équipé d'une ventilation forcée doit être utilisé à la charge assignée avec un ou plusieurs moteurs de ventilateur rendus inopérants en empêchant physiquement leur rotation. Si plusieurs moteurs de ventilateur sont concernés, l'analyse du 4.2 doit démontrer si un moteur après l'autre ou plus en même temps doivent être bloqués, en tenant compte d'une *condition de premier défaut*.

NOTE Pour éviter les dangers pendant cet essai, la rotation peut être physiquement empêchée avant de mettre le moteur de ventilateur sous tension.

5.2.4.13.3 Essai de filtre colmaté (*essai de type*)

Les *BDM/CDM/PDS* sous enveloppe comportant des ouvertures de ventilation filtrées doivent fonctionner à la charge assignée avec leurs ouvertures fermées afin de simuler des filtres colmatés.

L’essai doit d’abord être effectué avec 50 % des ouvertures de ventilation fermées en surface. L’essai doit être répété avec les ouvertures de ventilation totalement fermées.

5.2.4.13.4 Essai de perte de liquide de refroidissement (*essai de type*)

Un *BDM/CDM/PDS* refroidi par liquide doit fonctionner à la charge assignée. La perte du liquide de refroidissement doit être simulée en purgeant le liquide de refroidissement, en bloquant le flux ou en désactivant la pompe du liquide de refroidissement du *système*.

Si le *BDM/CDM/PDS* est arrêté en raison du fonctionnement d'un dispositif thermique dans le liquide de refroidissement, l'essai doit être répété après avoir purgé le liquide de refroidissement du *système*.

NOTE Par hypothèse, le dispositif thermique est inopérant s'il n'est pas enveloppé de liquide de refroidissement.

5.2.4.13.5 Essai de couverture des ouvertures pour l'air de refroidissement (*essai de type*)

Toutes les ouvertures d'un *BDM/CDM/PDS déplaçable* sont couvertes simultanément.

Il n'est pas nécessaire de bloquer les ouvertures de plus de 1,8 m.

5.2.5 Essais de matériaux

5.2.5.1 Généralités

Lorsque cela est exigé par 4.4.7.8.2, les propriétés d'inflammabilité des matériaux utilisés pour les besoins de l'isolation doivent être soumises à l'essai, comme cela est défini en 5.2.5.2, en 5.2.5.3 et en 5.2.5.4.

Lorsque cela est exigé par 4.6.4.2, les propriétés d'inflammabilité des matériaux utilisés pour l'*enveloppe ignifuge* doivent être soumises à l'essai, comme cela est défini en 5.2.5.5.

NOTE Aux États-Unis, les essais des matériaux ne sont pas exigés.

5.2.5.2 Essai de formation d'arc à courant élevé (*essai de type*)

Cinq échantillons d'essai de chaque matériau isolant à soumettre à l'essai sont utilisés (voir la Figure 26). Les échantillons doivent avoir une longueur minimale de 130 mm, une largeur de 13 mm et une épaisseur uniforme représentant la section la plus mince de la partie. Les bords doivent être exempts de toutes bavures, etc.

Chaque essai est effectué avec une paire d'électrodes d'essai et une charge à impédance inductive variable reliée en série à une source de courant de 220 V à 240 V en courant alternatif, 50 Hz ou 60 Hz (voir la Figure 26).

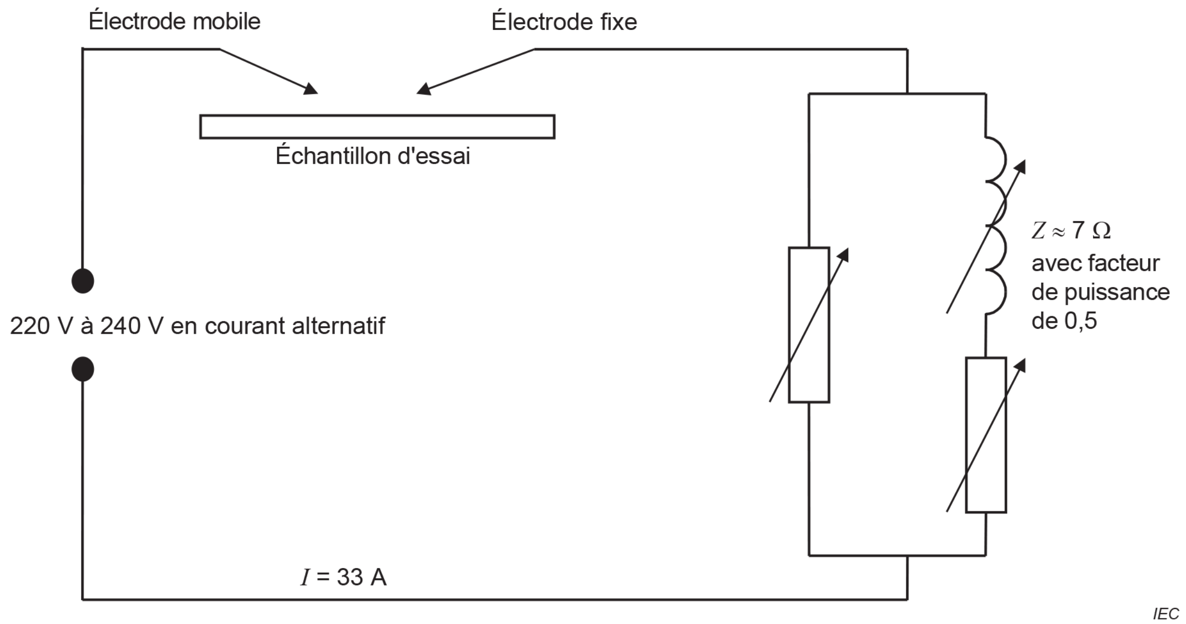


Figure 26 – Circuit pour essai de formation d'arc à courant élevé

Il est admis d'utiliser un circuit équivalent.

Une électrode est fixe et l'autre est mobile. L'électrode fixe se compose d'un conducteur en cuivre massif d'un diamètre de 3,5 mm avec une pointe formant un angle de 30°. L'électrode mobile est une tige d'acier inoxydable de 3 mm de diamètre avec une pointe conique symétrique ayant un angle total de 60° et qui peut être déplacée le long de son axe. Le rayon de courbure des extrémités des électrodes ne dépasse pas 0,1 mm au début d'un essai donné. Les électrodes sont disposées l'une en face de l'autre, dans le même plan, à un angle de 45° par rapport à l'horizontale. Avec les électrodes en court-circuit, la charge à impédance inductive variable est réglée jusqu'à ce que le courant soit de 33 A avec un facteur de puissance de 0,5.

L'échantillon soumis à l'essai repose sur un plan horizontal à l'air libre ou sur une surface non conductrice, de sorte que les électrodes, lorsque l'une touche l'autre, sont en contact avec la surface de l'échantillon. L'électrode mobile est commandée de façon manuelle ou par tout autre moyen, de sorte qu'elle puisse être désolidarisée de l'électrode fixe afin de rompre le circuit, et abaissée afin de le rétablir, afin que se produise une série d'arcs à un rythme d'environ 40 arcs/min, avec une vitesse de séparation de 250 mm/s ± 25 mm/s.

L'essai se poursuit jusqu'à ce que l'échantillon s'enflamme, qu'un trou se forme dans l'échantillon ou qu'un nombre total de 200 arcs ait eu lieu.

Le nombre moyen d'arcs nécessaires à l'inflammation des échantillons soumis à l'essai doit être conforme au Tableau 11.

5.2.5.3 Essai au fil incandescent (*essai de type*)

L'essai au fil incandescent doit être effectué selon l'IEC 60695-2-10:2021 et l'IEC 60695-2-13:2021 aux conditions spécifiées en 4.4.7.8.2.

Si l'essai doit être effectué au moins en deux points différents sur le même échantillon, il convient d'assurer que toute déformation due à des essais précédents n'affecte pas l'essai à effectuer.

NOTE En fonction de la classification de l'utilisation du *BDM/CDM*, l'essai au fil incandescent est réalisé à la température d'essai inférieure selon l'IEC 60695-2-11:2021, Figure A.1, mais pas à moins de 550 °C ou de la température applicable de 850 °C. La température d'essai est déduite de l'IEC 60695-2-11:2021, Annexe A, pour les équipements pour une utilisation imprévue chargés en permanence.

5.2.5.4 Essai d'inflammation au fil chaud (*essai de type* – alternative à l'essai au fil incandescent)

L'essai d'inflammation au fil chaud est une alternative à l'essai au fil incandescent.

Cinq échantillons de chaque matériau isolant sont évalués (voir la Figure 27). Les échantillons doivent avoir une longueur minimale de 130 mm, une largeur de 13 mm et une épaisseur uniforme représentant la section la plus mince de la partie. Les bords doivent être exempts de toutes bavures, etc.

Un fil de nichrome d'une longueur de 250 mm ± 5 mm (composition nominale de 80 % de nickel, 20 % de chrome, sans fer) d'un diamètre d'environ 0,5 mm et ayant une résistance à froid proche de 5 Ω/m est utilisé. Le fil est relié sur toute sa longueur à une source de puissance variable qui est réglée afin de générer une puissance de 0,25 W/mm ± 0,01 W/mm dans le fil pendant une durée de 8 s à 12 s. Après refroidissement, le fil est enroulé autour d'un échantillon afin de constituer cinq tours complets séparés de 6 mm.

L'échantillon enroulé repose sur un plan horizontal (voir la Figure 27) et les extrémités du fil sont reliées à la source de puissance variable, qui fait de nouveau l'objet d'un réglage pour générer une puissance de 0,25 W/mm ± 0,01 W/mm dans le fil.

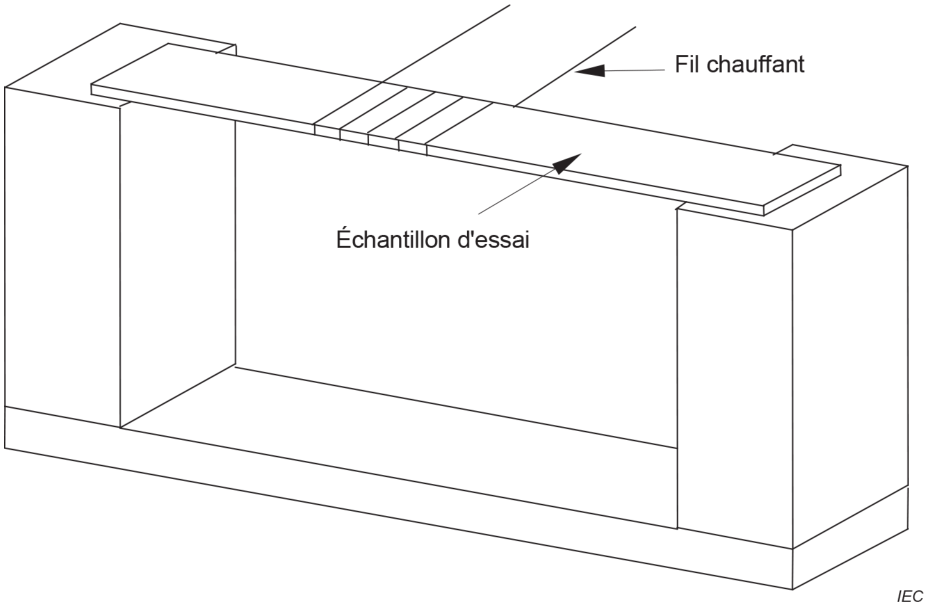


Figure 27 – Montage pour essai d'inflammation au fil chaud

L'essai se poursuit jusqu'à ce que l'échantillon s'enflamme ou que 120 s se soient écoulées. Lorsque l'inflammation se produit ou que 120 s se sont écoulées, l'essai est interrompu et la durée de l'essai est consignée. Pour les échantillons qui fondent sous le fil sans s'enflammer, l'essai est interrompu lorsque l'échantillon n'est plus entièrement en contact avec l'ensemble des cinq tours de fil chauffant.

L'essai est répété avec les échantillons restants.

Le temps d'inflammation moyen des échantillons soumis à l'essai doit être conforme au Tableau 11.

5.2.5.5 Essai d'inflammabilité (*essai de type*)

Trois échantillons du *BDM/CDM* complet ou trois échantillons d'essai de son *enveloppe* constitutive (voir 4.6.4.2) doivent être soumis à l'essai d'inflammabilité. Les *composants* et autres parties susceptibles d'exercer une influence sur les caractéristiques de l'équipement doivent être laissés en place. Les échantillons d'essai doivent être conditionnés dans un four à circulation d'air entièrement ventilé pendant sept jours une température supérieure de 10 °C à la température d'utilisation maximale, telle que déterminée par l'essai d'échauffement du 5.2.3.10, mais pas à moins de 70 °C dans tous les cas. Avant de procéder aux essais, les échantillons doivent être conditionnés pendant au moins 4 h à 23 °C ± 2 °C et 50 % ± 5 % d'humidité relative. La flamme doit être appliquée sur une surface interne de l'échantillon en un point jugé susceptible de s'enflammer du fait de sa proximité immédiate avec une source d'inflammation y compris les surfaces comportant des orifices d'aération. Lorsque plusieurs parties se trouvent à proximité immédiate d'une source d'inflammation, chaque échantillon doit être soumis à l'essai en appliquant la flamme en un point différent.

Les trois échantillons d'essai doivent présenter les performances acceptables décrites ci-dessous. En cas de non-conformité de l'un des échantillons, l'essai doit être répété sur un ensemble de trois nouveaux échantillons, la flamme étant appliquée dans les mêmes conditions que celles utilisées pour l'échantillon n'ayant pas satisfait à l'essai. Le matériau est déclaré acceptable si tous les nouveaux échantillons sont conformes aux exigences décrites ci-dessous.

Le brûleur de laboratoire, le réglage et l'étalonnage doivent être identiques à ceux décrits dans l'IEC 60695-11-20:2015.

Lorsqu’une *enveloppe* complète est utilisée pour réaliser l’essai à la flamme, l’échantillon doit être monté comme cela est prévu lors de son utilisation, dans la mesure où cela n’affecte pas l’essai à la flamme, à savoir dans une enceinte ou une *enveloppe* d’essai, voire une hotte de laboratoire, non ventilée. Une couche de coton hydrophile pur doit être placée à une distance de 305 mm en dessous du point d’application de la flamme d’essai. La flamme de 127 mm doit être appliquée en tout point de la surface interne de la partie jugée susceptible de s’enflammer (du fait de sa proximité immédiate avec des *parties actives* ou participant à la formation de l’arc, des bobines, des câblages et éléments similaires) à un angle, dans la mesure du possible, d’environ 20 ° par rapport à la verticale, de façon à ce que la pointe du dard bleu touche l’échantillon. La flamme d’essai doit être appliquée en trois points différents sur chacun des trois échantillons soumis à l’essai. Un dispositif d’alimentation en gaz méthane de qualité technique doit être utilisé en association avec un régulateur et un compteur permettant d’assurer un débit de gaz uniforme. Il s’est avéré qu’un gaz naturel dont l’enthalpie est approximativement de 37 MJ/m3 à une température de 23 °C fournit des résultats similaires et peut être utilisé.

La durée d’application et la durée de retrait de la flamme doivent être de 5 s. La manœuvre doit être répétée jusqu’à ce que l’échantillon ait été soumis à cinq applications de la flamme d’essai.

Les conditions suivantes doivent être remplies à l’issue de cet essai:

- la combustion du matériau ne doit pas se poursuivre au-delà de 1 min au terme de la cinquième application d’une durée de 5 s de la flamme d’essai, avec un intervalle de 5 s entre chaque application de la flamme;
- l’échantillon ne doit émettre, pendant toute la durée de l’essai, aucune gouttelette ni particule enflammée ou incandescente qui enflamme le coton hydrophile situé 305 mm en dessous.

Après l'essai, le *BDM/CDM* doit satisfaire aux exigences de *protection principale* au moyen d'*enveloppe* ou de barrières du 4.4.3.3.

5.2.5.6 Essai des joints scellés (*essai de type*)

Lorsque cela est exigé par 4.4.7.9, des échantillons représentatifs de joints scellés assurant une protection de type 1 ou de type 2 comme cela est défini dans l'IEC 60664-3:2016 doivent être soumis à l'*essai de type*, comme suit. Pour connaître la quantité d'échantillons soumis à l'essai, voir IEC 60664-3:2016.

Les échantillons doivent être préconditionnés selon 5.2.3.16.

Après le préconditionnement, les échantillons doivent passer les essais suivants dans l'ordre indiqué.

a) La résistance mécanique du joint doit être évaluée en lui appliquant des forces dont il est prévu qu'elles soient présentes dans les conditions normales. Les parties ne doivent pas se séparer.
b) La résistance d'*isolation* entre les parties conductrices séparées par le joint doit être mesurée selon l'IEC 60664-3:2016, 5.8.3. La valeur minimale de la résistance d'*isolation* entre les conducteurs doit être de 100 MΩ.
c) L'assemblage mécanique complet ou un échantillon équivalent doit être soumis à l'essai en tant qu'*isolation solide* selon 4.4.7.8.
d) Le sectionnement du joint ne doit présenter aucune fissure, aucun vide ni aucune séparation lors de l'*inspection visuelle* du 5.2.1 selon l'IEC 61189-3:2007, 6.2 (essai 3V02).

5.2.5.7 Essai de résistance aux ultraviolets (UV) (*essai de type*)

Lorsque cela est exigé par 4.12.9 pour les *enveloppes* polymères à usage extérieur, les *essais de type* doivent être réalisés afin de démontrer une résistance suffisante aux UV.

Les échantillons prélevés des parties ou composés d'un matériau identique sont préparés selon la norme relative à l'essai à réaliser (voir l'IEC 62109-1:2010, Tableau 27). Ils sont conditionnés aux UV conformément à l'IEC 62109-1:2010, Annexe J.

Après le conditionnement, les échantillons ne doivent présenter aucun signe de détérioration importante (craquelure ou fissures, par exemple). Ils sont ensuite conservés à température ambiante pendant au moins 16 h et pas plus de 96 h, période à l'issue de laquelle ils sont soumis à l'essai selon la norme de l'essai correspondant.

Pour évaluer le pourcentage de rétention des propriétés après l'essai, les échantillons qui n'ont pas été conditionnés selon l'Annexe J de l'IEC 62109-1:2010 sont soumis à l'essai en même temps que les échantillons conditionnés.

À l'exception de la classification d'inflammabilité (voir 4.6), utiliser l'IEC 62109-1:2010, Tableau 27, pour connaître les limites minimales de rétention de propriété après l'essai.

5.2.6 Essais environnementaux (*essais de type*)

5.2.6.1 Généralités

Des essais environnementaux sont exigés pour établir la sécurité du *BDM/CDM/PDS* aux extrêmes de la classification environnementale à laquelle il est soumis selon 4.9.

NOTE Aux États-Unis et au Canada, les essais environnementaux ne sont pas exigés.

Si des considérations de dimension ou de puissance entravent les performances de ces essais sur le *BDM/CDM/PDS* complet, des essais sur les parties individuelles liées à la sécurité du *BDM/CDM/PDS* sont admis.

Si les *composants* ou sous-ensembles sont soumis à l'essai séparément, la température lors de l'essai de chaleur sèche doit être choisie de manière à simuler l'utilisation réelle dans le produit final. Le *composant* ou le sous-ensemble doit être mis sous tension en simulant les mêmes conditions que celles du produit final.

Le Tableau 38 présente les essais à réaliser pour les différentes conditions environnementales.

La conformité est démontrée en procédant à l'essai du 5.2.6.3, du 5.2.6.4, du 5.2.6.5, du 5.2.6.6 et du 5.2.6.7 conformément au Tableau 38 selon le cas pour les conditions environnementales spécifiées par le fabricant.

S'il est spécifié que le *BDM/CDM/PDS* fonctionne hors de la plage de valeurs indiquée dans le présent document, les conditions d'essai doivent respecter la plage de valeurs indiquée dans les documents d'utilisation. Dans tous les cas, les exigences d'essai ne doivent pas être moins contraignantes que les conditions de fonctionnement spécifiées.

Tableau 38 – Essais environnementaux

Condition d'essai	Intérieur sans condition	Extérieur sans condition
Norme	IEC 60721-3-3:1994, 60721-3-3/AMD1:1995 et 60721-3-3/AMD2:1996 [b]	IEC 60721-3-4:2019
Climatique	Procédure de préconditionnement ou de recouvrement pour les essais climatiques (voir 5.2.6.3.1)	Procédure de préconditionnement ou de recouvrement pour les essais climatiques (voir 5.2.6.3.1)
	Chaleur sèche (voir 5.2.6.3.2) Essai Bd de l'IEC 60068-2-2:2007	Chaleur sèche (voir 5.2.6.3.2) Essai Bd de l'IEC 60068-2-2:2007
	Essai à basse température (voir 5.2.6.3.3) Essai Ad de l'IEC 60068-2-1:2007	Essai à basse température (voir 5.2.6.3.3) Essai Ad de l'IEC 60068-2-1:2007
	Chaleur humide (essai continu) (voir 5.2.6.3.4) Essai Cab de l'IEC 60068-2-78:2012	Chaleur humide (essai continu) (voir 5.2.6.3.4) Essai Cab de l'IEC 60068-2-78:2012
	Aucune exigence d'essai	Chaleur humide (cyclique) (voir 5.2.6.3.5) Essai Db de l'IEC 60068-2-30:2005
Substances chimiquement actives	Aucune exigence d'essai	Essai Kb de l'IEC 60068-2-52:2017 Brouillard salin [a] (voir 5.2.6.5)
Substances mécaniquement actives	Aucune exigence d'essai	Essai Lc de l'IEC 60068-2-68:1994 Poussière et sable (voir 5.2.6.6 et 5.2.6.7)
Mécanique	Essai Fc de l'IEC 60068-2-6:2007 Vibration (voir 5.2.6.4)	Essai Fc de l'IEC 60068-2-6:2007 Vibration (voir 5.2.6.4)
Biologique	Aucune exigence d'essai	Aucune exigence d'essai
Résistance aux UV	Aucune exigence d'essai	5.2.5.7

[a] Voir la note de bas de page [a] du Tableau 20.

[b] Dans le présent document, aucun essai à basse température n'est exigé dans le cadre d'une utilisation en intérieur.

Si des conditions environnementales particulières sont spécifiées, des essais supplémentaires (pour les substances chimiquement actives, par exemple) doivent être envisagés.

5.2.6.2 Critères d'acceptation

Les critères d'acceptation suivants doivent être satisfaits:

a) aucune dégradation de *composant* lié à la sécurité des *BDM/CDM/PDS*;

b) aucun comportement potentiellement dangereux des *BDM/CDM/PDS* pendant l'essai;

c) aucun signe de surchauffe des *composants*;

d) aucune *partie active dangereuse* ne doit devenir accessible;

e) aucune fissure dans l'*enveloppe* et aucun isolant endommagé ou desserré;

f) réussite de l'essai de tension en courant alternatif ou en courant continu individuel de série du 5.2.3.4;

g) réussite de l'essai de continuité de *liaison équipotentielle de protection* du 5.2.3.11.2;

h) aucun comportement potentiellement dangereux lors de l'utilisation du *BDM/CDM/PDS* après l'essai.

5.2.6.3 Essais climatiques

5.2.6.3.1 Procédure de préconditionnement ou de recouvrement pour les essais climatiques (*essai de type*)

La procédure de préconditionnement ou de recouvrement pour les essais climatiques doit être réalisée comme cela est indiqué dans le Tableau 39.

Tableau 39 – Procédure de préconditionnement ou de recouvrement pour les essais climatiques (*essai de type*)

Procédure de préconditionnement ou de recouvrement	
– Temps	1 h minimum
– Conditions climatiques	
• Température	15 °C à 35 °C non régulée ou comme cela est exigé dans l'essai individuel
• Humidité relative	25 % à 75 %, non régulée
• Pression barométrique	86 kPa à 106 kPa
– Alimentation	Alimentation non connectée
– Condensation pour la procédure de recouvrement uniquement	Toute condensation interne ou externe doit être retirée par un flux d'air avant d'effectuer l'essai de tension en courant alternatif ou en courant continu ou de reconnecter le *BDM/CDM/PDS* à une alimentation.
NOTE Les valeurs de ce tableau sont conformes à celles du Tableau 24.	

5.2.6.3.2 Essai de chaleur sèche (régime permanent) (*essai de type*)

Pour démontrer l'aptitude des *composants* et du *BDM/CDM/PDS* à fonctionner, à être transportés ou à être stockés à des températures élevées, l'essai de chaleur sèche (régime permanent) doit être réalisé selon les conditions spécifiées dans le Tableau 40.

Tableau 40 – Essai de chaleur sèche (régime permanent) (*essai de type*)

Objet	Conditions d'essai
Sélection initiale et *inspection visuelle* avant l'essai	Selon le 5.1.2 et le 5.2.1
Procédure de préconditionnement	Selon le Tableau 39
Essai	
Référence d'essai	IEC 60068-2-2:2007, Essai Bd
Référence des exigences	4.9
Conditions de fonctionnement	Fonctionnement aux conditions assignées
– Température	Classification de la température selon la température élevée du Tableau 20 ou la température maximale spécifiée par le fabricant, si cette dernière est plus sévère.
– Exactitude	±2 °C (voir l'IEC 60068-2-2:2008)
– Humidité	25 % à 75 % non régulée
– Durée de l'exposition	≥ 16 h
Procédure de recouvrement	Selon le Tableau 39.

5.2.6.3.3 Essai à basse température (*essai de type*)

Pour démontrer l'aptitude des *composants* et des *BDM/CDM/PDS* à fonctionner, à être transportés ou à être stockés à de basses températures, l'essai à basse température doit être réalisé selon les conditions spécifiées dans le Tableau 41.

Tableau 41 – Essai à basse température (*essai de type*)

Objet	Conditions d'essai
Choix initial et *inspection visuelle* avant l'essai	Selon le 5.1.2 et le 5.2.1
Procédure de préconditionnement	Selon le Tableau 39
Essai	
Référence des exigences	4.9
Référence d'essai	IEC 60068-2-1, Essai Ad
Conditions de fonctionnement	Après le préconditionnement et la stabilisation, début du fonctionnement selon la spécification du fabricant. Le fonctionnement doit être démontré par l'*inspection visuelle* de 5.2.1, par mesurage ou en appliquant une charge.
Précautions particulières	Les pertes thermiques liées au fonctionnement de l'échantillon d'essai ne doivent pas avoir d'impact sur le résultat d'essai.
Température	Classification de la température selon la basse température du Tableau 20 ou la température la plus basse spécifiée par le fabricant, si cette dernière est plus sévère.
Exactitude	±3 °C (voir l'IEC 60068-2-1)
Humidité	Non régulée
Durée de l'exposition	≥ 16 h
Procédure de recouvrement	Selon le Tableau 39.

5.2.6.3.4 Essai de chaleur humide (régime permanent) (*essai de type*)

Pour prouver la résistance à l'humidité, le *BDM/CDM/PDS* doit être soumis à un essai de chaleur humide (régime permanent) selon les conditions spécifiées dans le Tableau 42.

Tableau 42 – Essai de chaleur humide (régime permanent) (*essai de type*)

Objet	Conditions d'essai
Choix initial et *inspection visuelle* avant l'essai	Selon le 5.1.2 et le 5.2.1
Procédure de préconditionnement	Selon le Tableau 39
Essai	
Référence d’essai	IEC 60068-2-78:2012, Essai Cab
Référence des exigences	4.9
Conditions de fonctionnement Précautions particulières Température Exactitude Humidité Exactitude Durée de l’exposition	Alimentation non connectée Les sources internes de tension peuvent rester connectées si la chaleur qu’elles produisent dans l’échantillon est négligeable. 40 °C ±2 °C (voir l’IEC 60068-2-78:2012, Article 5) 93 % d'humidité relative régulée ou humidité la plus élevée spécifiée par le fabricant, si cette dernière est plus sévère. ±3 % (voir l’IEC 60068-2-78:2012, Article 5) ≥ 96 h
Procédure de recouvrement	Selon le Tableau 39.

5.2.6.3.5 Essai de chaleur humide (cyclique) (*essai de type*)

Pour démontrer la résistance des *composants* et des *BDM/CDM/PDS* à la condensation, un essai de chaleur humide (cyclique) selon les conditions spécifiées dans le Tableau 43 doit être réalisé si de la condensation est attendue.

Tableau 43 – Essai de chaleur humide (cyclique) (*essai de type*)

Objet	Conditions d'essai
Choix initial et *inspection visuelle* avant l'essai	Selon le 5.1.2 et le 5.2.1
Procédure de préconditionnement	Selon le Tableau 39
Essai	
Référence d'essai	IEC 60068-2-30:2005, Essai Db, variante 2
Référence des exigences	4.9
Conditions de fonctionnement	Après le préconditionnement et la stabilisation, début du fonctionnement selon la spécification du fabricant. Le fonctionnement doit être démontré par l'*inspection visuelle* de 5.2.1, par mesurage ou en appliquant une charge.
Précautions particulières	Les pertes thermiques liées au fonctionnement de l'échantillon d'essai ne doivent pas avoir d'impact sur le résultat d'essai.
Humidité	Voir l'IEC 60068-2-30:2005, Figure 2b
Exactitude	±3 % d'humidité relative (voir l'IEC 60068-2-30:2005)
Durée de l'exposition	Voir l'IEC 60068-2-30:2005, Figure 2b
Température inférieure	25 °C
Température supérieure	40 °C
Exactitude	±3 °C (voir l'IEC 60068-2-30:2005)
Nombre de cycles	2 (48 h)
Temps de montée et de descente de la température	Voir l'IEC 60068-2-30:2005, Figure 2b
Procédure de recouvrement	Selon le Tableau 39

5.2.6.4 Essai de vibration (*essai de type*)

Pour vérifier la résistance mécanique aux vibrations, le *BDM/CDM/PDS* associé à son *installation* doit être évalué par

a) les essais définis en 5.2.6.4 selon les conditions spécifiées dans le Tableau 44, ou

b) calcul ou simulation s'appuyant sur des essais, comme cela est défini en 5.2.6.4, sur un modèle représentatif de *BDM/CDM/PDS*.

Pour les *BDM/CDM/PDS* dont la masse est supérieure à 100 kg, cet essai peut être effectué sur des sous-ensembles.

NOTE Pour les grands *BDM/CDM/PDS*, la possibilité d'utiliser un essai de choc à la place d'un essai de vibration est à l'étude.

Tableau 44 – Essai de vibration

Objet	Conditions d'essai
Référence d'essai	Essai Fc de l'IEC 60068-2-6:2007
Référence des exigences	4.9
Choix initial et *inspection visuelle* avant l'essai	Selon le 5.1.2 et le 5.2.1
Conditions	Alimentation non connectée
Mouvement Amplitude/accélération de la vibration 10 Hz ≤ f ≤ 58 Hz 58 Hz ≤ f ≤ 150 Hz Durée de la vibration	Sinusoïdal 0,075 mm d'amplitude 10 m/s^2 (1 g) 10 cycles de balayage par axe sur chacun des trois axes mutuellement perpendiculaires
Détail du montage	Selon les spécifications du fabricant
Nombre d'échantillons pour les essais	1 échantillon pour tous les axes
Lorsque le fabricant spécifie des niveaux de vibration plus élevés que ceux ci-dessus, ces niveaux supérieurs doivent être utilisés pour l'essai. Les critères d'acceptation ne doivent pas être changés. NOTE Cet essai est un essai accéléré, ce qui signifie que le niveau est supérieur à celui indiqué dans le Tableau 20.	

5.2.6.5 Essai de brouillard salin (*essai de type*)

Pour vérifier la résistance au brouillard salin, le *BDM/CDM/PDS* associé à son *installation* doit être évalué par les essais définis en 5.2.6.5 selon les conditions spécifiées dans le Tableau 45.

Tableau 45 – Essai de brouillard salin

Objet	Conditions d'essai
Référence d'essai	Essai Kb de l'IEC 60068-2-52:2017
Référence des exigences	Tableau 38
Choix initial et *inspection visuelle* avant l'essai	Selon le 5.1.2 et le 5.2.1
Conditions	Alimentation non connectée
Niveau de sévérité	Méthode d'essai 2
Critères d'acceptation	5.2.6.2
Lorsque le *fabricant* du *BDM/CDM/PDS* spécifie des niveaux de brouillard salin plus élevés que ceux ci-dessus, ces niveaux supérieurs doivent être utilisés pour l'essai. Les critères d'acceptation ne doivent pas être changés. Si les conditions environnementales sont réputées inférieures, le *fabricant* du *BDM/CDM/PDS* peut spécifier un niveau inférieur ou aucun essai de brouillard salin autres que ceux spécifiés dans ce tableau. Les critères d'acceptation ne doivent pas être changés.	

5.2.6.6 Essai de poussière (*essai de type*)

Pour vérifier l'aptitude à fonctionner en présence de poussière, le *BDM/CDM/PDS* associé à son *installation* doit être évalué par les essais définis en 5.2.6.6 dans les conditions spécifiées dans le Tableau 46, essentiellement pour démontrer l'étanchéité à la poussière.

Pour les *BDM/CDM/PDS* dont la masse est supérieure à 100 kg, cet essai peut être effectué sur des sous-ensembles.

Tableau 46 – Essai de poussière

Objet	Conditions d'essai
Référence d'essai	En fonction de la classe IP choisie de l'IEC 60529
Référence des exigences	Tableau 38
Choix initial et *inspection visuelle* avant l'essai	Selon le 5.1.2 et le 5.2.1
Conditions	Alimentation non connectée
Dimension des particules	Selon l'IEC 60529
Concentration de poussière	Selon l'IEC 60529
Vitesse de l'air	Selon l'IEC 60529
Pression atmosphérique dans l'échantillon	Selon l'IEC 60529
Durée de l'essai	Selon l'IEC 60529
Critères d'acceptation	5.2.6.2 et selon la classification IP choisie de l'IEC 60529

5.2.6.7 Essai de sable (*essai de type*)

Pour vérifier l'aptitude à fonctionner en présence de sable, le *BDM/CDM/PDS* associé à son *installation* doit être évalué par les essais définis en 5.2.6.7 dans les conditions spécifiées dans le Tableau 47, essentiellement pour démontrer la résistance à l'abrasion par le sable.

Tableau 47 – Essai de sable

Objet	Conditions d'essai
Référence d'essai	Essai Lc1 de l'IEC 60068-2-68:1994
Référence des exigences	Tableau 38
Choix initial et *inspection visuelle* avant l'essai	Selon le 5.1.2 et le 5.2.1
Conditions	Alimentation non connectée
Dimension des particules	Poussière fine
Concentration de poussière	2 g/m³
Vitesse de l'air	5 m/s
Pression atmosphérique dans l'échantillon	La pression atmosphérique dans l'échantillon est celle de la pression atmosphérique ambiante.
Durée de l'essai	24 h
Critères d'acceptation	5.2.6.2

5.2.7 Essai de pression hydrostatique (*essai de type*, *essai individuel de série*)

Pour les *essais de type*, la pression dans le *système* de refroidissement d'un *BDM/CDM/PDS* refroidi par liquide (voir 4.7.4.3.3) doit être progressivement augmentée jusqu'à ce qu'un limiteur de pression (s'il est fourni) fonctionne, ou jusqu'à ce qu'une pression égale à deux fois la pression de fonctionnement ou 1,5 fois la pression nominale maximale du *système*, si cette dernière valeur est plus grande, soit atteinte.

Pour les besoins de cet essai, la pompe du liquide de refroidissement peut être désactivée.

Pour les *essais individuels de série*, la pression doit être augmentée à la pression nominale maximale du *système*.

Tant pour l'*essai de type* que pour l'*essai individuel de série*, un liquide adapté doit être utilisé pour détecter les fuites.

NOTE 2 Un essai préalable à l'*essai individuel de série* avec de l'air comprimé peut être réalisé.

La pression doit être maintenue pendant au moins une minute.

Critères d'acceptation:

- l'essai ne doit entraîner aucun danger thermique, danger de choc électrique ou autre danger;
- il ne doit y avoir aucune fuite de liquide de refroidissement ou aucune perte de pression pendant l'essai, autre que celle d'un limiteur de pression pendant un *essai de type*;
- Le *BDM/CDM/PDS* doit réussir l'essai de tension en courant alternatif ou en courant continu du 5.2.3.4 après l'*essai de type* de pression hydrostatique.

5.2.8 Essai de champs électromagnétiques (CEM) (*essai de type*)

Voir l'Article P.4.

6 Exigences relatives aux informations et au marquage

6.1 Généralités

6.1.1 Vue d'ensemble

L'Article 6 a pour objet de définir les informations nécessaires à la sélection, à l'installation et à la mise en service, au fonctionnement et à la maintenance des *BDM/CDM/PDS* en toute sécurité dans le cadre de son utilisation prévue.

Cela est présenté dans le Tableau 48, qui indique les endroits où les informations doivent être fournies, suivi de paragraphes explicatifs. En cas de contradictions, les exigences du texte des articles sont obligatoires.

Sauf indication contraire, les exigences de l'Article 6 s'appliquent à tous les *BDM/CDM/PDS*.

Dans la mesure où tout appareillage électrique peut être installé ou utilisé de telle manière que des conditions dangereuses peuvent se produire, la satisfaction aux exigences de conception du présent document ne garantit pas d'elle-même une installation en toute sécurité. Toutefois, lorsque des appareillages conformes à ces exigences sont correctement sélectionnés, installés et utilisés, les dangers sont réduits le plus possible.

Le manuel doit informer que, pour les besoins de l'installation, du fonctionnement et de la maintenance, un manuel doit être mis à disposition de l'utilisateur final au moment de l'installation du *BDM/CDM/PDS*.

Le manuel doit mentionner également tous les dangers potentiels qui peuvent découler d'une mauvaise utilisation raisonnablement prévisible du *PDS*.

Toutes les informations doivent être rédigées dans la langue appropriée, et les documents doivent comporter des références d'identification. Les symboles des schémas doivent être conformes à l'IEC 60417 ou l'IEC 60617, selon le cas. Les symboles non indiqués dans l'IEC 60417 ou l'IEC 60617 doivent être identifiés lorsqu'ils sont utilisés.

La conformité aux exigences relatives aux informations et au marquage des paragraphes 6.1 à 6.5 est vérifiée par *inspection visuelle* en 5.2.1.

Le système SI doit être utilisé lors de la spécification d'unités électriques, mécaniques et thermiques.

NOTE 1 Aux États-Unis, les unités de mesure hors système pouce-pied-livre sont largement utilisées.

NOTE 2 Aux États-Unis et au Canada, les symboles internationaux ne sont pas utilisés en lieu et place du texte.

NOTE 3 Au Canada, il existe deux langues officielles: l'anglais et le français. Le paragraphe T.6.2.1.200 donne les traductions équivalentes en français des marquages spécifiés dans le présent document.

NOTE 4 Des recommandations supplémentaires sont fournies par l'IEC 61082-1:2014 pour la préparation de la documentation, et par l'IEC/IEEE 82079-1:2019 pour la préparation des instructions et des manuels.

Tableau 48 – Exigences d'informations

Informations	**Références de paragraphe**	**Emplacement [a, b, c]**					**Références de paragraphe technique**	**Pratiques nationales [h]**
		1	**2**	**3**	**4**	**5**		
Identification du produit [d]	6.2.1.2	X	X		X	X	4.1	x
Caractéristiques assignées électriques pour chaque *accès* [d]	6.2.1.3 S.6.2.1.200.1 T.6.3.9.6.200	X	X			X	4.1	x
	S.6.2.1.200.2					X		États-Unis
Informations supplémentaires relatives à *chaque accès*	6.2.1.4 T.6.3.9.6.200					X	4.1	
BDM/CDM/PDS refroidi par liquide [d, g]	6.2.1.5	X	X	X		X	4.1, 4.7.4	x
Marquages généraux du *BDM/CDM/PDS*	6.2.1.6					X	4.1	x – plusieurs équipements assignés uniquement
		X						Canada
Instructions et marquages relatifs aux accessoires [b, d, g, e]	6.2.2	X	X		X	X	4.1	x
Considérations d'ordre mécanique	6.3.2					X	4.1	
Classification IP pour les *BDM/CDM/PDS* sous enveloppe	6.3.2, S.6.2.1	X				X	4.1, 4.12.1 T.4.12.1	x
Informations relatives aux masses [d]	6.3.2	X	X		X	X	4.1	
Environnement	6.3.3 T.6.3.3					X	4.9, 4.4.7.1.3, 4.6.5	x – caractéristique assignée de température ambiante uniquement
Utilisation dans des compartiments de traitement de l'air	S.6.3.3		X			X		États-Unis
Manutention et montage	6.3.4					X	4.2	
Température de l'enveloppe	6.3.5 T.6.3.5.200					X	4.6.5.3	x

Informations	**Références de paragraphe**	**Emplacement** [a, b, c]					**Références de paragraphe technique**	**Pratiques nationales** [h]
		1	**2**	**3**	**4**	**5**		
BDM/CDM de *type ouvert* [d]	6.3.6					X	4.4.3.3.4, 4.6.4.3, 4.6.5	x
Connexion, câblage, conducteurs, et bornes	6.3.7, S.6.3.7.2					X	4.1, 4.2, 4.11.1	x
Identification des *bornes pour câblage externe*	6.3.7.4.1, S.6.3.7.4.1	X	X	X		X	4.4.6.5.3, 4.11.5, 4.11.11.3	x
Autres précisions relatives aux *bornes pour câblage externe* [f]	6.3.7.4.2 d)					X	--	x
Fiches et socles de prise de courant *réseau*	6.3.7.5	X	X	X		X	4.11.7	
Mise en service	6.3.8					X	4.1, 4.2	
Exigences de protection	6.3.9	X				X	4.3, 4.4.3.3.2, 4.4.4.3, 4.4.6, 4.4.8, 4.11.5,	
Circuit de *liaison équipotentielle de protection* [g]	6.3.9.3	X	X			X	4.4.4.2, 4.4.4.3.2	
Moyens externes de protection	6.3.9.6, S.6.3.9.6.1, S.6.3.9.6.2, S.6.3.9.6.3, S.6.3.9.6.4					X	4.1, 4.2, 4.3.2, 4.4.4.4, 4.4.7.2	x
Courant de contact ou courant de fuite élevé	6.3.9.4	X				X	4.4.4.3.3	X
Compatibilité avec le DDR	6.3.9.5	X				X	4.4.8	
Moyens de protection pour les *BDM/CDM/PDS* reliés par un cordon	S.6.3.9.6.5					X	S.4.11.10.1	États-Unis
Protection contre la surcharge et la surchauffe du moteur [d, g]	6.3.9.7 T.6.3.9.7.201			X		X	4.3.5.2, 4.3.5.3, 4.3.5.4	X
	T.6.3.9.7.200		X					Canada
Surface combustible	T.6.3.5.200	X					4.6.5.3 T.4.12.201	Canada
Moteur et matériel entraîné	6.3.10					X	4.3.5.5, 4.4.7, 4.7.2, 4.7.3	
Composants installés sur le terrain	6.3.11					X	4.12.1, T.4.12.1	X
Moyens de liaison de l'*enveloppe* installés sur le terrain	T.6.3.9.6.200		X				S.4.4.4.2.200	États-Unis
Informations pour l'utilisation	6.4.1, S.6.4.1					X	4.1	X
Réglage	6.4.2					X	4.2	
Dispositif d'isolation et de déconnexion	6.4.3.2	X	X	X		X	4.1, 4.2	
Surface brûlante	6.4.4	X				X	4.6.5.3, 5.2.4.13.1	X
Marquage des commandes et du dispositif	6.4.5		X			X	4.3	X
Stabilité des BDM/*CDM/PDS posés* au sol	6.4.6					X	4.12.5	
Plusieurs usines	T.6.4.200	X						Canada

Informations	Références de paragraphe	Emplacement [a, b, c]					Références de paragraphe technique	Pratiques nationales [h]
		1	2	3	4	5		
Divers	T.6.4.202	X						Canada
Capot amovible	S.6.5.1	X					S.4.12.201.10.1 e)	États-Unis
Date de fabrication [d]	6.5.1.2	X	X				4.1	
Informations de sécurité	6.5.1.3					X	4.1	
Décharge de condensateurs	6.5.2	X	X	X		X	4.4.9, 4.5.2.2	X
Mode de fonctionnement spécial – Redémarrage automatique/connexion de dérivation	6.5.3					X	4.1	X
Autres dangers	6.5.4					X	4.1, 4.2	
Radiateurs sous tension (et autres parties)	S.6.5.4	SUR LA PARTIE						États-Unis
BDM/CDM/PDS à plusieurs sources d'alimentation	6.5.5	X				X	4.8	X
Connexion TP/TI	6.5.6		X			X	4.1, 4.2	X
Conditions d'accès au *PDS*/*CDM*/PDS haute tension pendant la maintenance	6.5.7					X	4.4.10	

[a] Emplacement:

1. Sur un *BDM/CDM/PDS* sous enveloppe, visible lorsque le *capot* de l'*enveloppe* est ouvert et que la *porte* est fermée (voir 6.4.3).
2. Sur un *BDM/CDM* de *type ouvert* ou sous enveloppe, visible lors de l'ouverture d'une *porte* ou du retrait d'un *capot* (voir 6.4.3).
3. Sur un *BDM/CDM* de *type ouvert*, séparer l'étiquette autoadhésive qui accompagne le dispositif.
4. Sur l'emballage.
5. Manuels d'installation, d'utilisation et/ou de maintenance.

Pour les emplacements de marquage 1, 2 et 3, plus d'un X signifie que n'importe lequel des emplacements marqués d'un X peut être utilisé.

[b] Les manuels d'installation, d'utilisation et de maintenance peuvent être combinés selon le cas et, si cela est acceptable par le client, peuvent être fournis en format informatique.

[c] Quand plus d'un des produits est fourni à un seul client, il n'est pas nécessaire de fournir un manuel avec chaque produit.

[d] Pour les *BDM/CDM* de *type ouvert*, voir 6.2.1.6.

[e] Le marquage des *accessoires* non fournis avec le *BDM/CDM/PDS* doit suivre les instructions relatives au marquage de 6.2.2.

[f] Les parties non montées sur le *BDM/CDM/PDS* doivent être marquées selon 6.3.7.4.2 d).

[g] Des informations peuvent être placées sur le produit ou dans le manuel d'utilisation, mais si elles sont placées uniquement dans le manuel d'utilisation, le marquage du 6.1.3 s'applique.

[h] Si le marquage "X" est indiqué, les informations s'appliquent aux États-Unis d'Amérique et au Canada. Les lignes ne faisant référence qu'à l'Annex S ou à l'Annex T s'appliquent uniquement aux États-Unis d'Amérique ou au Canada.

6.1.2 Documentation au format électronique

Si la documentation est fournie au format électronique uniquement, les informations suivantes doivent être données sur le produit lui-même ou sur un feuillet d'information

- l'emplacement de téléchargement de cette documentation (l'URL, par exemple), et
- où une copie papier de la documentation peut être commandée.

Lorsqu'une URL est fournie, elle doit être sous une forme lisible à l'œil nu. De manière facultative, un code lisible par machine peut également être fourni.

NOTE Le QR code est un exemple de code lisible par machine.

Un avertissement doit être fourni sur le *BDM/CDM/PDS* par le symbole ISO 7010-M002:2011-05 (voir le Tableau C.1).

Si le marquage ou les informations sont fournis au format électronique conformément à la désignation d'emplacement "5" (voir la note de bas de page [b] du Tableau 48), le marquage suivant, ou un équivalent, est fourni sur le dispositif ou sur un feuillet d'information fourni avec le *BDM/CDM/PDS* qui doit être retiré pour installer ou connecter le *BDM/CDM/PDS*. Si le marquage est posé sur le dispositif, il doit indiquer:

> "AVERTISSEMENT – Consulter le manuel du produit avant d'installer ou d'utiliser le *BDM/CDM/PDS*."

Si le marquage est indiqué dans un feuillet d'information, ce dernier doit indiquer:

> "AVERTISSEMENT – Le fonctionnement de cet équipement fait l'objet d'instructions d'installation et de fonctionnement détaillées indiquées dans le manuel d'installation/utilisation en relation avec ce produit. Ces informations sont fournies sur un autre dispositif de stockage électronique qui accompagne le *BDM/CDM/PDS*. Il convient de les conserver avec ce *BDM/CDM/PDS*. Une copie papier de ces informations peut être obtenue auprès du fabricant (*lequel ajoute la méthode utilisée pour fournir la copie papier, c'est-à-dire le numéro de téléphone, l'adresse, la page web, etc.)*".

6.1.3 Instructions d'installation

S'il est admis d'apposer des informations sur le produit ou dans le manuel d'installation, et si ces dernières ne sont fournies que dans le manuel d'installation, le marquage suivant, ou un équivalent, est fourni sur le dispositif ou sur un feuillet d'information imprimé accompagnant le *BDM/CDM/PDS*:

> "AVERTISSEMENT – Le fonctionnement de cet équipement fait l'objet d'instructions d'installation et de fonctionnement détaillées indiquées dans le manuel d'installation/utilisation en relation avec ce produit"

ou le symbole d'action obligatoire ISO 7010-M002 (voir le Tableau C.1).

NOTE Aux États-Unis et au Canada, le symbole d'action obligatoire ISO 7010-M002 n'est pas reconnu.

6.2 Informations relatives à la sélection

6.2.1 Généralités

6.2.1.1 Généralités

Comme cela est exigé en 4.1, chaque partie d'un *PDS* qui est fournie comme produit séparé doit être accompagnée des informations relatives à l'utilisation prévue liée à sa fonction, ses caractéristiques électriques et son environnement d'utilisation prévu (voir 6.3.3) de manière à pouvoir déterminer son aptitude à l'emploi et sa compatibilité avec les autres parties du *PDS*. Pour un *BDM/CDM*, ces informations comprennent, entre autres, 6.2.1.2, 6.2.1.3, 6.2.1.4, 6.2.1.5 et 6.2.1.6.

6.2.1.2 Identification du produit

a) le nom ou la marque du fabricant, du fournisseur ou de l'importateur;

b) le numéro catalogue ou un équivalent.

6.2.1.3 Caractéristiques assignées électriques pour chaque *accès*

a) tension d'entrée nominale maximale;

b) tension de sortie nominale maximale;

c) courant de sortie nominal maximal (voir 5.2.3.12) ou puissance nominale de sortie;

NOTE 1 Aux États-Unis, la puissance nominale de sortie est exprimée en cheval-vapeur (voir le Tableau S.29 et le Tableau S.30). Si la caractéristique assignée est le courant et la puissance, les valeurs de courant et de puissance du Tableau S.29 et du Tableau S.30 sont utilisées.

NOTE 2 Au Canada, la puissance nominale de sortie est exprimée en cheval-vapeur (voir le Tableau T.12 et le Tableau T.13). Si la caractéristique assignée est le courant et la puissance, les valeurs de courant et de puissance du Tableau T.12 et du Tableau T.13 sont utilisées.

NOTE 3 Au États-Unis d'Amérique, la caractéristique assignée de tension est soit directe (480 V en courant alternatif, par exemple), ce qui représente un *système* TN avec une phase à la terre, ou une caractéristique assignée de tension oblique (480/277 V en courant alternatif, par exemple) qui représente un *système* TN avec mise à la terre du neutre.

d) caractéristique assignée de cycle de service pour les *BDM/CDM/PDS* conçus pour fonctionner de manière intermittente (voir 5.2.3.10);

NOTE 4 L'IEC TR 61800-6 donne des informations relatives aux caractéristiques assignées de cycle de service du *BDM/CDM/PDS* et l'IEC 61800-2:2021, 5.3.3.3, des informations relatives aux caractéristiques assignées de surintensité du *BDM/CDM/PDS.*

e) valeur efficace de courant d'entrée nominal maximal pour le dimensionnement des éléments de protection contre les surcharges et le câblage;

f) nombre de phases (3 en courant alternatif, par exemple);

g) plage de fréquences nominales (50 Hz à 60 Hz, par exemple);

h) classe de protection (I, II, III), voir 6.3.9.2;

i) un circuit CTD *As* doit être durablement marqué de manière visible après l'installation afin d'indiquer la classe d'alimentation et sa caractéristique assignée électrique (par exemple, 30 Vac, CTD As), ou un équivalent; et

j) un circuit CTD As destiné à être alimenté par un transformateur ou une source d'alimentation externe sur le terrain doit être marqué "CTD As" en regard de la tension nominale du dispositif (30 V en courant alternatif, CTD As, par exemple), ou un équivalent.

6.2.1.4 Informations supplémentaires relatives à chaque *accès*

a) plusieurs équipements assignés;

b) classification *CTD* selon 4.4.2.1;

c) pour un circuit CTD As n'ayant fait l'objet d'aucune évaluation dans des emplacements humides et mouillés à l'eau salée, l'une des informations suivantes, selon ce qui s'applique selon le Tableau 20, ou une formulation équivalente:

   – "Ne pas utiliser dans des emplacements humides"; ou

   – "Ne pas utiliser dans des emplacements mouillés à l'eau salée";

d) catégorie de surtension électrique (voir 4.4.7.1.4);

e) le type de *système* d'alimentation électrique (par exemple, TN, IT, etc.) auquel le *BDM/CDM/PDS* peut être raccordé (voir 4.4.7.1.5);

f) caractéristiques d'allègement thermique pour un fonctionnement à une altitude supérieure à 1 000 m ou par l'élévation de la température ambiante;

g) caractéristique(s) assignée(s) de courant de court-circuit des

   – *courants conditionnels de court-circuit* (I_{cc}) et *valeur* minimale exigée *du courant de court-circuit présumé* $I_{cp,mr}$ et caractéristiques du *dispositif de protection contre les courts-circuits* selon 4.3.2.2,
   – *courant de court-circuit en sortie* disponible selon 4.3.2.3,
   – caractéristiques des dispositifs de protection, selon 4.3.2 et 5.2.4.5,
   – *accès* de puissance d'entrée et de sortie combinés 4.3.2.4,
   – exigences en alimentation électrique de la charge (le cas échéant), et
   – alimentation d'inducteur pour les moteurs en courant continu (le cas échéant).

6.2.1.5 *BDM/CDM/PDS* refroidi par liquide

Comme cela est exigé en 4.7.4, les informations suivantes doivent être fournies pour les *BDM/CDM/PDS* refroidis par liquide:

a) le type de réfrigérant liquide;
b) la pression de fonctionnement nominale;
c) la pression de fonctionnement maximale.

6.2.1.6 Marquages généraux du *BDM/CDM/PDS*

a) utilisation prévue (voir 4.1);
b) accessoires admis (voir 4.1);
c) équipements auxiliaires spécifiques (voir 4.1);
d) la ou les références à la ou aux normes appropriées pour le fabricant, l’essai ou l’utilisation;
e) la référence à la documentation d’installation, d’utilisation et de maintenance.

Les informations doivent se limiter à l’essentiel pour une sélection appropriée et il convient qu’elles soient propres à un équipement spécifique. Si les informations couvrent un grand nombre de variantes de produits, il doit être possible de les différencier facilement.

Pour les *BDM/CDM* de *type ouvert*, il n'est pas exigé que le marquage soit visible s'ils sont montés côte à côte ou à proximité d'autres dispositifs.

Pour les *BDM/CDM/PDS* destinés à être utilisés dans différentes applications exigeant différentes dispositions de câblage avec les caractéristiques assignées électriques correspondantes, les caractéristiques assignées électriques du 6.2 peuvent être fournies dans la documentation de référence avec le *BDM/CDM/PDS* lorsque ce dernier est marqué:

> "Plusieurs équipements assignés. Voir le manuel d'instruction."

ou une déclaration équivalente.

6.2.2 Instructions et marquages relatifs aux *accessoires*

Comme cela est exigé en 4.1, les marquages du *BDM/CDM/PDS* doivent inclure l'identification d'un *accessoire* à fixer dans le domaine ou une référence à une publication séparée qui identifie ce type d'*accessoires*. Pour les *BDM/CDM/PDS* tels qu'un dispositif ouvert pour lequel le marquage exigé se trouve sur une feuille séparée, les informations relatives à l'accessoire peuvent également se trouver sur une feuille séparée.

Les *accessoires* conçus pour un produit existant doivent être marqués avec l'identification du *BDM/CDM/PDS* sur lequel ils sont destinés à être utilisés.

Les *accessoires* qui ne sont pas livrés par l'usine dans le même emballage que le *BDM/CDM/PDS* avec lequel ils sont destinés à être utilisés doivent être totalement marqués avec ce qui suit:

a) nom du fabricant, la marque ou un autre marquage descriptif par lequel l'organisme responsable du produit est identifiable;
b) numéro de catalogue ou un équivalent;
c) autres informations, comme cela est spécifié dans les paragraphes 6.3 à 6.5.

6.3 Informations pour l'installation et la mise en service

6.3.1 Généralités

Comme cela est exigé en 4.1, une installation sûre et fiable relève de la responsabilité de l'installateur, du fabricant de la machine et/ou de l'utilisateur. Le fabricant de toute partie du *BDM/CDM/PDS* doit fournir des informations afin de soutenir cette tâche. Ces informations ne doivent pas être ambiguës et peuvent se présenter sous forme schématique.

6.3.2 Considérations d'ordre mécanique

Comme cela est exigé en 4.1, les informations suivantes doivent être fournies:

a) classification IP pour les *BDM/CDM/PDS* sous enveloppe en 4.12.1*;*

   NOTE 1 Aux États-Unis, le classement environnemental est utilisé en lieu et place de la classification IP, conformément à S.4.12. Si le classement environnemental indique une utilisation intérieure de Type 4X uniquement, les lettres du marquage sont lisibles et de police et hauteur identiques.

   NOTE 2 Au Canada, le classement environnemental est utilisé en lieu et place de la classification IP, conformément à T.4.12.1.

b) schéma des dimensions;
c) schéma de montage;
d) informations relatives aux masses;
e) surfaces supérieures, si elles sont exigées en 4.4.3.3.5.1 ou en 4.4.3.3.5.2.

Pour les *BDM/CDM/PDS* intégrés dans des *équipements enfichables de type A,* le marquage de la classification IP sur le produit n'est pas obligatoire.

Pour les *BDM/CDM/PDS* d'une masse maximale de 18 kg, le marquage des informations relatives aux masses sur le produit n'est pas obligatoire.

6.3.3 Environnement

Comme cela est exigé en 4.1, le manuel doit spécifier les conditions environnementales suivantes pour le fonctionnement, le transport et le stockage, selon 4.9:

a) conditions climatiques (*température ambiante*, conditions d'humidité, altitude, exposition aux ultraviolets, etc.);
b) éléments mécaniques (vibration, choc, chute, basculement, etc.);
c) *degré de pollution* pour lequel le *BDM/CDM/PDS* a été conçu, comme cela est exigé en 4.4.7.1.3;
d) exigences relatives au chauffage pour empêcher la condensation, comme cela est exigé en 4.4.7.1.3.

NOTE Les catégories environnementales spécifiées dans l'IEC 60721 (toutes les parties) peuvent être utilisées quand cela est approprié.

6.3.4 Manutention et montage

Afin de prévenir toute blessure ou tout dommage, comme cela est exigé en 4.2, les documents d'installation doivent inclure des avertissements relatifs à tous les dangers susceptibles d'apparaître au cours de l'installation. Lorsque cela est nécessaire, des instructions doivent être prévues pour

a) l'emballage et le déballage,
b) le déplacement,
c) le levage,
d) la solidité et la rigidité de la surface de montage,
e) la fixation, et
f) les dispositions d'accès appropriées pour le fonctionnement, le réglage et la maintenance.

6.3.5 *Température* de l'enveloppe

Si les températures de surface du *BDM/CDM/PDS*, à proximité des surfaces de montage, dépassent la limite du 4.6.5.3, le manuel d'installation doit contenir un avertissement relatif à l'installation du *BDM/CDM/PDS* sur un matériau non combustible.

Le marquage suivant, ou un équivalent, doit être apparaître:

> "Convient à un montage uniquement sur des surfaces en béton ou autres surfaces non combustibles".

Voir également 6.4.4.

6.3.6 *BDM/CDM* de *type ouvert*

6.3.6.1 Protection contre le feu pour *BDM/CDM* de *type ouvert*

Lorsque cela est exigé par 4.6.4.3 ou 4.6.5, le manuel d'installation doit inclure le texte d'avertissement suivant (ou un équivalent):

> "Ce *BDM/CDM* de *type ouvert* n'a pas vocation à diminuer les dangers d'incendie. Il est destiné à être installé à l'intérieur d'une *enveloppe* supplémentaire ou dans une *zone d'accès limité* qui assure une protection appropriée contre la propagation du feu."

Si le *BDM/CDM* de *type ouvert* est soumis à l'essai selon 5.2.4.1 3), la dimension minimale et la méthode de ventilation de l'*enveloppe* doivent être décrites.

6.3.6.2 Protection contre les chocs électriques non fournie par les *enveloppes* ou les barrières

Lorsque cela est exigé par 4.4.3.3.4, le manuel d'installation doit inclure le texte d'avertissement suivant (ou un équivalent):

> "Ce *BDM/CDM* de *type ouvert* n'assure pas la protection contre le contact direct des *parties actives dangereuses*. Il est destiné à être installé à l'intérieur d'une *enveloppe* supplémentaire ou dans une *zone d'accès limité* qui assure une protection appropriée contre les chocs électriques."

6.3.6.3 Température de fonctionnement

6.3.6.3.1 *Température ambiante* de fonctionnement

Pour les *BDM/CDM/PDS* sous enveloppe dans lesquels la *température ambiante* maximale est inférieure à celle exigée dans le Tableau 20, un marquage est exigé.

NOTE Aux États-Unis et au Canada, la *température ambiante* maximale doit être marquée dans l'emplacement 1 du Tableau 48, si la caractéristique assignée de *température ambiante* est inférieure à 40 °C. Si la caractéristique de *température ambiante* est supérieure à 40 °C, elle doit se trouver dans l'emplacement 5 du Tableau 48. Si la caractéristique assignée de *température ambiante* est égale à 40 °C, aucun marquage ni aucune instruction n'est exigé.

6.3.6.3.2 *Température de l'air ambiant environnant* de fonctionnement

Un *BDM/CDM/PDS* de *type ouvert* évalué selon 5.2.3.10 doit être marqué

"*Température de l'air ambiant environnant maximale (type ouvert*)__°C".

6.3.7 Connexions

6.3.7.1 Généralités

Toutes les exigences particulières concernant les câbles et les connexions doivent être identifiées dans les manuels d’installation et de maintenance, comme cela est exigé en 4.11.3.

Des informations doivent être fournies pour permettre à l’installateur de procéder à une connexion électrique sécurisée du *BDM/CDM/PDS*. Cela doit inclure les informations concernant la protection contre les dangers (par exemple, choc électrique, disponibilité de l’énergie et système de câblage spécial) qui peuvent être rencontrés pendant l’installation, le fonctionnement ou la maintenance.

6.3.7.2 Schémas d’interconnexion et de câblage

Comme cela est exigé en 4.1 et en 4.2, les manuels d’installation et de maintenance doivent comporter des informations détaillées sur toutes les connexions nécessaires, ainsi qu’un schéma d’interconnexion recommandé, comme cela est exigé en 4.11.8.

6.3.7.3 Sélection des conducteurs (câbles)

Le manuel d'installation doit définir les niveaux de tension et de courant pour toutes les *bornes pour câblage externe* du *BDM/CDM/PDS*, accompagnés des exigences d’*isolation* des câbles. Ces niveaux doivent être les valeurs des cas les plus défavorables, compte tenu des conditions de court-circuit et de surcharge et des effets possibles des courants non sinusoïdaux, comme cela est exigé en 4.11.2.

6.3.7.4 Identification et autres précisions relatives aux *bornes pour câblage externe*

6.3.7.4.1 Identification des *bornes pour câblage externe*

L’identification de toutes les *bornes pour câblage externe* doit être apposée sur les *BDM/CDM/PDS*, soit directement, soit par une étiquette fixée à proximité des bornes (voir 4.11.5 et 4.11.11.3).

Les manuels d’installation et de maintenance doivent identifier toutes les bornes externes des circuits protégés par l’une des méthodes décrites en 4.4.6.5.3 en matière de raccordement aux circuits *TBTP* et circuits*TBTS* externes.

Si la borne de *mise à la terre de protection* ne se trouve pas à proximité de ses bornes d'entrée ou de sortie associées, une description est exigée pour assurer une mise à la terre correcte du *système*. Voir la 4.11.11.3.

Une borne de connexion du conducteur de neutre doit être aisément identifiable par son emplacement et/ou son marquage et sa couleur, comme cela est exigé en 4.11.5, à partir des autres bornes. D'autre part, une identification correcte de la borne pour la connexion du conducteur de neutre doit être clairement indiquée d'une autre manière (fixée sur un schéma de câblage, par exemple).

6.3.7.4.2 Autres précisions relatives aux *bornes pour câblage externe*

Pour assurer la sécurité de l'installation, la documentation doit spécifier les éléments suivants a), b), c), d) et e) le cas échéant:

a) Caractéristiques des bornes

– plage des dimensions et des types de conducteurs acceptables (mono ou multibrins) pour toutes les bornes (voir 4.11.11.2);

– nombre maximal de conducteurs pouvant être reliés simultanément en parallèle par borne;

– dimension des moyens de fixation (voir d)).

NOTE 1 Aux États-Unis, le type de conducteur, le nombre de conducteurs par borne et la dimension des moyens de fixation ne sont pas exigés. Si une borne de câblage n'est pas destinée à recevoir un conducteur d'une dimension plus importante que celle spécifiée en S.4.11.11.2, alors la documentation doit être marquée de manière à limiter son usage au conducteur de dimension plus petite. Dans le cas contraire, la dimension du conducteur n'est pas exigée.

b) Valeur de couple de serrage

– valeur nominale ou plage de valeurs de couple de serrage;

– résistance exigée des boulons et des écrous.

NOTE 2 Aux États-Unis, le couple de serrage spécifié ne doit pas être inférieur à 90 % de la valeur utilisée dans l'essai de chaleur statique comme cela est spécifié dans les exigences de la norme Standard for Wire Connectors, UL 486A-486B ou Standard for Equipment Wiring Terminals for Use With Aluminum and/or Copper Conductors, UL 486E.

NOTE 3 Aux États-Unis, il n'est pas exigé que la valeur du couple de serrage soit égale à 90 % de la valeur spécifiée lorsque le connecteur est examiné selon l'UL 486A-486B ou l'UL 486E avec la valeur de couple assignée inférieure.

NOTE 4 Aux États-Unis, il n'est pas exigé de marquer une *borne pour câblage externe* destinée uniquement à la connexion d'un conducteur de *circuit de commande* avec une valeur de couple de serrage lorsque l'essai est réalisé selon les exigences applicables de l'UL 486A-486B ou l'UL 486E, avec une valeur de couple de serrage de 7 lbf·in (0,8 Nm).

c) Type de câble et température

– si les bornes sont adaptées à la connexion de conducteurs en cuivre et/ou en aluminium et/ou en aluminium plaqué de cuivre;

– les exigences de caractéristiques assignées de température d'*isolation* pour le conducteur ou le câble en fonction des résultats de l'essai de température du 5.2.3.10. Voir 4.11.11.2.

NOTE 5 Aux États-Unis et au Canada, les *bornes pour câblage externe* des connecteurs épaissis à l'aluminium ou destinés à être utilisés avec un fil d'aluminium doivent être marquées AL7CU ou AL9CU pour l'*isolation* des fils à 60 °C ou 75 °C.

NOTE 6 Aux États-Unis et au Canada, les *BDM/CDM/PDS* doivent être marqués de manière à indiquer les caractéristiques assignées de température (60 °C uniquement, 60/75 °C ou 75 °C uniquement) utilisées dans l'évaluation des *bornes pour câblage externe* de puissance. Il n'est pas exigé de marquer les bornes de *circuit de commande* de manière à indiquer les caractéristiques assignées de température.

d) *Accessoires* pour la connexion des fils

- la longueur de dénudage du fil;
- les cosses en anneau, les férules, les fils, les vis de serrage de câble ou les serre-fils à pression;
- un serre-fil à pression ou des kits d'*accessoires* de borne de *composant*;
- *accessoires* de câblage tels que des écrous, des boulons, des rondelles élastiques;
- *accessoires* de fixation et de cheminement des câbles.

e) *Composants* de bornes

- si les *composants* de borne ne sont pas livrés avec l'équipement, la documentation doit indiquer les kits de bornes de *composant* destinés à être utilisés avec l'équipement;
- si des parties d'un bornier (par exemple, cosses ou partie amovible des connecteurs en deux parties) ne sont pas livrées avec l'équipement, la documentation doit indiquer les kits de bornes destinés à être utilisés avec l'équipement, ou les normes du commerce relatives à ces borniers.

6.3.7.5 Fiches et socles de prise de courant *réseau*

Lorsque cela est exigé en 4.11.7, la tension doit être marquée sur les fiches et socles de prise de courant *réseau* qui acceptent des fiches réseau normalisées, si elle est différente de la tension *réseau*. Si le socle de prise de courant réseau est destiné à être utilisé avec un *BDM/CDM/PDS* particulier, il doit être marqué de manière à identifier le *BDM/CDM/PDS* auquel il est destiné. Si ce n'est pas le cas, la puissance ou le courant assigné maximal doit être marqué ou le symbole ISO 7010-W001:2011-05 présenté dans le Tableau C.1 être placé à côté du socle de prise de courant réseau avec tous les détails inclus dans la documentation.

6.3.8 Mise en service

Si des *essais de mise en service* sont nécessaires pour assurer la sécurité électrique et thermique d'un *BDM/CDM/PDS*, des informations pour la prise en charge de ces essais doivent être fournies pour chaque partie du *PDS*. Ces informations peuvent dépendre de l'*installation* spécifique, une coopération étroite entre le fabricant, l'installateur et l'utilisateur pouvant être exigée.

Comme cela est exigé en 4.1 et en 4.2, les informations de mise en service doivent comprendre les références aux dangers qui peuvent être rencontrés lors de la mise en service, par exemple ceux mentionnés en 6.4 et en 6.5.

6.3.9 Exigences de protection

6.3.9.1 *Parties accessibles* et *circuits accessibles*

6.3.9.1.1 Généralités

Lorsque cela est exigé par 4.4.3.3.2 pour l'utilisation dans les *zones d'accès pour la maintenance*, les manuels d'installation, d'utilisation et de maintenance doivent identifier toutes les *parties accessibles* conductrices ayant des tensions supérieures à la *CTD As* et doivent décrire les dispositions en matière d'*isolation* et de séparation exigées pour la protection.

Les manuels doivent également indiquer les précautions à prendre pour assurer le maintien de la sécurité des connexions *CTD As* pendant l'installation.

En cas de danger après le trait d'un *capot* ou d'un *BDM/CDM/PDS* sous enveloppe (voir 4.4.3.3.2), une étiquette d'avertissement doit être placée sur le *BDM/CDM/PDS*. L'étiquette doit être visible avant le retrait du *capot*.

NOTE Si l'étiquette d'avertissement est placée sur un *capot*, il n'est plus obligatoire qu'elle soit visible lorsque le *capot* est retiré.

Le manuel d'un *BDM/CDM/PDS* doit indiquer la tension maximale admise à relier à chaque *accès*.

Les manuels doivent fournir les instructions concernant l'utilisation de circuits *TBTP* et de circuits *TBTS* à l'intérieur d'une *zone de liaison équipotentielle de protection*.

6.3.9.1.2 Exigences relatives aux méthodes alternatives dans la *zone d'accès pour la maintenance*

Pour assurer la sécurité du personnel lors des opérations de maintenance et/ou d'entretien indiquées par le fabricant (voir 4.4.3.3.2 b)), le manuel d'installation et de maintenance doit être fourni pour permettre au personnel de maintenance de prendre des précautions et de travailler en sécurité si l'équipement est sous tension. Ce manuel doit

a) donner des instructions détaillées relatives aux opérations de maintenance et d'entretien exigées dans une *zone d'accès pour la maintenance* dont l'entrée exige un outil ou une clé,
b) formellement mettre en évidence toutes les conditions dangereuses qui existent dans la zone du produit où une opération d'entretien ou de maintenance est exigée, et
c) inclure l'emplacement spécifique d'une énergie potentiellement dangereuse électrique mécanique, etc.

6.3.9.2 Classe de protection

6.3.9.2.1 Généralités

Le manuel d'installation doit déclarer la classe de protection spécifiée pour le *BDM/CDM/PDS* comme cela est exigé par 4.4.6 et 4.4.4.3.3 et le produit doit être marqué selon les exigences du 6.3.9.2.2, du 6.3.9.2.3 et du 6.3.9.2.4.

6.3.9.2.2 *BDM/CDM/PDS* relevant de la *classe de protection I*

Les bornes pour la connexion du *conducteur de mise à la terre de protection* exigées par 4.4.4.3.2 et 4.11.5 doivent comporter un marquage clair et indélébile d'un ou de plusieurs des éléments suivants:

a) le symbole IEC 60417-5019:2006-08 (voir le Tableau C.1);
b) les lettres PE;
c) le codage couleur vert ou vert et jaune.

NOTE Aux États-Unis et au Canada, le symbole IEC 60417-5017:2006-08 ou le symbole IEC 60417-5019:2006-08 ou la formulation "G," "GR," "GRD," "Terre," "Mise à la terre," ou analogue peut être utilisé(e). Une vis de serrage destinée à relier le *conducteur de mise à la terre de protection* d'un équipement installé sur le terrain doit avoir une tête hexagonale et/ou fendue de couleur verte.

Lorsque cela est exigé par 4.11.5, la documentation doit spécifier des instructions claires relatives à l'emplacement du *conducteur de mise à la terre de protection* et à la connexion correcte à la borne.

6.3.9.2.3 *BDM/CDM/PDS* relevant de la *protection de classe II*

Les *BDM/CDM/PDS* relevant de la *classe de protection II* doivent être marqués du symbole IEC 60417-5172:2003-02 (voir le Tableau C.1). Lorsque ce type de *BDM/CDM/PDS* permet la connexion d'un conducteur de mise à la terre pour des raisons fonctionnelles (voir 4.4.6.3), ce moyen de connexion doit être marqué du symbole IEC 60417-5018:2011-07 (voir le Tableau C.1).

6.3.9.2.4 *BDM/CDM/PDS* relevant de la *classe de protection III*

Les *BDM/CDM/PDS* relevant de la *classe de protection III* doivent être marqués du symbole IEC 60417-5180:2003-02 (voir le Tableau C.1).

Aucun marquage n'est exigé sur le produit.

6.3.9.3 Circuit de *liaison équipotentielle de protection*

Le circuit de *liaison équipotentielle de protection* du 4.4.4.2 doit être marqué comme suit.

a) Pour les moyens de connexion du *conducteur de mise à la terre de protection* du 4.4.4.3.2, voir 6.3.9.2.2.

NOTE 1 Le texte suivant est copié de l'IEC 60204-1:2016, 13.2.2 et a été modifié.

b) Le conducteur de *liaison équipotentielle de protection* interne doit pouvoir être aisément distingué des autres conducteurs par sa forme, son emplacement, son marquage ou sa couleur.
c) S'il peut être aisément identifié par sa forme, sa position ou sa construction (conducteur tressé, conducteur toronné non isolé, par exemple), aucun marquage supplémentaire n'est exigé.
d) Si l'identification est assurée par sa couleur uniquement, une combinaison des couleurs verte et jaune doit être utilisée sur toute la longueur du conducteur ou, si le conducteur isolé n'est pas aisément accessible ou fait partie d'un câble multiconducteur, le codage couleur sur toute sa longueur n'est pas nécessaire. Toutefois, si le conducteur n'est pas clairement visible sur toute sa longueur, les extrémités ou les emplacements accessibles doivent être clairement identifiés par
   - le symbole IEC 60417-5017:2006-08,
   - la combinaison bicolore vert/jaune, ou
   - des marquages, s'ils sont expliqués dans la documentation.

NOTE 2 Le texte suivant est copié de l'IEC 62368-1:2018, F.3.6.1.1 et a été modifié.

e) Toutefois, si les bornes pour la connexion sont fournies sur un *composant* ou un sous-ensemble, le symbole IEC 60417-5017:2006-08 ou IEC 60417-5019:2006-08 est admis.

Lorsque cela est exigé en 4.4.4.2.1, lorsque les vis de connexion de la *liaison équipotentielle de protection* sont utilisées à d'autres fins, cela doit être spécifié dans la documentation.

6.3.9.4 *Courant de contact* ou courant de fuite élevé

6.3.9.4.1 Généralités

La documentation doit spécifier si au moins une des solutions proposées en 4.4.4.3.3 est applicable pour le *BDM/CDM/PDS*.

6.3.9.4.2 *Courant de contact*

Si le *courant de contact* dépasse les limites indiquées en 4.4.4.3.3, cela doit être indiqué dans les manuels d'installation et de maintenance. De plus, un symbole d'avertissement ISO 7010-W001:2011-05 ou ISO 7000-0434a:2004-01 ou ISO 7000-0434b:2004-01 (voir le Tableau C.1) doit être apposé sur le produit et une note doit être intégrée au manuel d'installation selon laquelle la dimension minimale du *conducteur de mise à la terre de protection* doit satisfaire aux réglementations locales en matière de sécurité pour des *BDM/CDM/PDS à courant de contact* élevé.

Lorsque cela est exigé par 4.4.4.3.3, le nombre maximal de *BDM/CDM/PDS* interconnectés doit être indiqué dans le manuel d'installation.

6.3.9.4.3 Courant de fuite élevé

Si le *courant du conducteur de mise à la terre de protection* dépasse les limites indiquées en 4.4.4.3.4, cela doit être indiqué dans les manuels d'installation et de maintenance. De plus, un symbole d'avertissement ISO 7010-W001:2011-05 ou ISO 7000-0434a:2004-01 ou

ISO 7000-0434b:2004-01 (voir le Tableau C.1) doit être placé sur le produit et une note doit être intégrée au manuel d'installation selon laquelle cette connexion des *parties accessibles constructrices* à proximité du *BDM/CDM/PDS* au circuit de *liaison équipotentielle de protection* du *BDM/CDM/PDS* est exigéed.

Le manuel d'installation doit spécifier si au moins une des solutions proposées en 4.4.4.3.4 est applicable pour le *BDM/CDM/PDS*.

6.3.9.5 Compatibilité avec le DDR

Les manuels d'installation et de maintenance doivent indiquer la compatibilité avec les DDR (voir 4.4.8). Lorsque 4.4.8 b) s'applique, une note et le symbole d'avertissement ISO 7010-W001:2011-05 ou ISO 7000-0434a:2004-01 ou ISO 7000-0434b:2004-01 (voir le Tableau C.1) doivent être fournis dans le manuel d'utilisation, et le symbole doit être apposé sur le produit. La mise en garde doit être la suivante (ou un équivalent):

> "Ce produit peut générer un courant continu dans le *conducteur de mise à la terre de protection*. Lorsqu'un dispositif de protection à courant différentiel résiduel (DDR) est utilisé pour la protection contre les chocs électriques, seul un DDR de type B est permis du côté de l'alimentation du produit. Tous les DDR en amont, jusqu'au transformateur d'alimentation, doivent être de Type B."

Voir 6.4.3 pour les exigences générales relatives aux étiquettes, aux panneaux et aux signaux.

NOTE Aux États-Unis et au Canada, cette exigence du 6.3.9.5 ne s'applique pas.

6.3.9.6 Moyens externes de protection

6.3.9.6.1 Généralités

Si des moyens externes de protection sont nécessaires pour assurer la protection contre les dangers, ils doivent être spécifiés dans le manuel d'installation et de maintenance.

6.3.9.6.2 Dispositifs de protection

Dans le cas où des dispositifs de protection sont exigés, les types exigés ou les caractéristiques des dispositifs de protection contre les *surintensités* (voir également 5.2.4 et 4.3.2.2, 4.3.2.3) doivent être spécifiés.

Pour les *BDM/CDM* de *type ouvert*, le fabricant doit indiquer si le dispositif de protection doit être installé dans la même *enveloppe* finale que le *BDM/CDM* (voir 5.2.4.6).

6.3.9.6.3 Protection selon l'IEC 60364-4-41:2005 et l'IEC 60364-4-41:2005/AMD1:2017, Articles 411 ou 415

Si le *BDM/CDM/PDS* satisfait aux exigences du 4.4.4.4.1 et du 4.4.4.4.2 ou du 4.4.4.4.3, le fabricant du *BDM/CDM/PDS* doit indiquer

a) les types ou les caractéristiques des dispositifs de protection (voir 4.4.4.4.2) utilisés pour satisfaire à l'essai du 5.2.4.5.3,

b) qu'un circuit électronique de protection satisfait aux exigences de l'IEC 60364-4-41:2005 et l'IEC 60364-4-41:2005/AMD1:2017, Article 411 (voir 4.4.4.4.3 1)), lorsqu'il est utilisé pour satisfaire à l'essai du 5.2.4.5.3, ou

c) que les exigences de la *liaison équipotentielle de protection* supplémentaire (voir 4.4.4.4.3 2)) au niveau du moteur ou d'une charge externe sont conformes à l'IEC 60364-4-41:2005 et à l'IEC 60364-4-41:2005/AMD1:2017, Article 415.

De plus, les conditions d'application des mesures de protection indiquées ci-dessus doivent être spécifiées. Il s'agit par exemple,

d) de la limitation de la longueur du câble vers le moteur,

e) de la section minimale des câbles du conducteur vers le moteur (conducteur de ligne, *conducteur de mise à la terre de protection*),

f) du type de câble, et

g) du type de *système* de mise à la terre de l'alimentation.

NOTE Une vérification initiale et régulière incluant la méthode de vérification est exigée par l'IEC 60364-4-41:2005 et l'IEC 60364-4-41:2005/AMD1:2017, Annexe D.

6.3.9.6.4 Dispositifs de protection contre les surtensions

Lorsque des *SPD* sont exigés à des fins de conformité avec 4.4.7.2.3 et 4.4.7.2.4, le manuel d'utilisation doit fournir des informations relatives à la sélection appropriée des *SPD* à installer dans l'*installation* fixe pour assurer une réduction correcte des surtensions.

6.3.9.7 Protection contre la surcharge et la surchauffe du moteur

6.3.9.7.1 ***BDM/CDM*** sans ***protection électronique contre la surcharge*** et la surchauffe ***du moteur***

Si le *BDM/CDM* ne comporte aucune protection électronique contre la surcharge ou contre la surchauffe du moteur, le manuel d'installation doit indiquer l'absence de ces protections. Voir 4.3.5.1 e).

6.3.9.7.2 ***BDM/CDM*** avec ***protection électronique*** interne ***contre la surcharge*** et la surchauffe ***du moteur***

Lorsque cela est exigé par 4.3.5.2, les manuels d'installation et de maintenance des *BDM/CDM* équipés d'une protection interne contre la surcharge doivent donner les informations suivantes:

a) protection en multiples du courant de réglage;

b) délai de déclenchement;

c) instructions de réglage.

Si la *protection électronique* interne *contre les surcharges du moteur* possède une *rétention de mémoire thermique* (voir 4.3.5.3), les manuels d'installation et de maintenance des *BDM/CDM* doivent fournir les informations sur son comportement. Lorsque la *rétention de mémoire thermique* est réglable, les manuels doivent être fournis avec des instructions pour le réglage.

Si la *protection électronique* interne *contre les surcharges du moteur* ne possède pas de *rétention de mémoire thermique* (voir 4.3.5.3), les manuels d'installation et de maintenance doivent fournir ces informations.

Si la *protection électronique* interne *contre les surcharges du moteur* est sensible à la vitesse (voir 4.3.5.4), les manuels d'installation et de maintenance des *BDM/CDM* doivent fournir des informations sur son comportement. Si la sensibilité à la vitesse est réglable, les manuels doivent donner les instructions relatives au réglage.

Si la *protection électronique* interne *contre les surcharges du moteur* n'est pas sensible à la vitesse (voir 4.3.5.4), cette information doit figurer dans les manuels d'installation et de maintenance.

6.3.10 Moteur et matériel entraîné

6.3.10.1 Sélection du moteur

Lorsque cela est nécessaire pour un *BDM/CDM*, les informations relatives aux spécifications appropriées du moteur doivent être fournies conformément à l'IEC 60034-1:2022. L'influence possible des réflexions des formes d'ondes de sortie du PWM sur l'*isolation* du moteur doit être prise en considération.

6.3.10.2 Capteurs intégrés au moteur

Pour assurer que le système d'isolation du *BDM/CDM/PDS* conçu selon 4.4.7 n'est pas enfreint, le manuel d'installation doit définir les exigences relatives aux capteurs intégrés dans le moteur. Voir également 4.3.5.1 c).

6.3.10.3 Vitesses de torsion critiques

Lorsque cela est exigé par 4.7.2, le fabricant du *PDS* doit donner toutes les informations nécessaires sur le moteur pour permettre d'identifier les vitesses de torsion critiques.

NOTE Voir également l'IEC 61800-2:2021, 5.13.

6.3.10.4 Analyse du couple transitoire

Lorsque cela est exigé par 4.7.3, le fabricant du *PDS* doit donner toutes les informations électriques et mécaniques pertinentes pour permettre l'analyse du couple transitoire.

NOTE Voir également l'IEC 61800-2:2021, 5.13.

6.3.11 *Composants* installés sur le terrain

Les *enveloppes* destinées à l'installation sur le terrain de *composants* essentiels pour l'intégrité de l'environnement de l'enveloppe doivent être marquées ou fournies avec des instructions qui identifient le *BDM/CDM/PDS* nécessaire pour maintenir l'intégrité de l'environnement de l'*enveloppe*. Cela peut être réalisé en identifiant le classement IP nécessaire ou en identifiant le fabricant ou numéro de modèle spécifique du *BDM/CDM/PDS* installé sur le terrain.

NOTE 1 Aux États-Unis, le classement environnemental est utilisé en lieu et place de la classification IP, conformément à S.4.12.201.2. Si le classement environnemental indique une utilisation intérieure de Type 4X uniquement, les lettres du marquage doivent être lisibles et de police et hauteur identiques.

NOTE 2 Au Canada, le classement environnemental est utilisé en lieu et place de la classification IP, conformément à T.4.12.1.

6.4 Informations pour l'utilisation prévue

6.4.1 Généralités

Comme cela est exigé en 4.1, le manuel de l'utilisateur doit inclure toutes les informations relatives au fonctionnement en toute sécurité des *BDM/CDM/PDS*. En particulier, il doit identifier tout

a) matériau dangereux,

b) risque de choc électrique,

c) surchauffe,

d) explosion, et

e) bruit acoustique excessif, etc. (voir 4.10.2).

6.4.2 Réglage

Comme cela est exigé en 4.2, le manuel de l'utilisateur doit donner des détails sur tous les réglages utilisateur liés à la sécurité. Le marquage de l'identification ou de la fonction de chaque dispositif de commande ou indicateur et de chaque dispositif de protection contre les *surintensités* doit être apposé à proximité de l'entité. Lorsque cela s'avère impossible à réaliser sur le produit, les informations doivent être données sous forme picturale dans le manuel.

Les réglages de maintenance qui ont un impact sur la sécurité doivent être décrits dans le manuel; et il doit être précisé clairement que ces réglages exigent une *personne qualifiée*.

Des avertissements distincts doivent être prévus lorsqu'un réglage excessif peut conduire à un état dangereux des *BDM/CDM/PDS*.

Tout appareillage spécial nécessaire pour effectuer des réglages doit faire l'objet d'une spécification et d'une description.

6.4.3 Étiquettes, panneaux, symboles et signaux

6.4.3.1 Généralités

L'étiquetage doit être conforme à des principes ergonomiques corrects, de sorte que les notes, commandes, indications, points d'essai, dispositifs de protection contre les *surintensités*, etc., soient placés en des points stratégiques et soient regroupés d'une façon logique facilitant une identification correcte et non ambiguë.

Toutes les étiquettes de prudence et d'avertissement du *BDM/CDM/PDS* relatives à la sécurité pour l'emplacement 2 selon le Tableau 48 indiquant un danger doivent être placées de manière à être visibles après l'installation ou aisément visibles en ouvrant une *porte* ou en retirant un *capot* lorsque le *BDM/CDM/PDS* est installé comme prévu, y compris côte à côte avec une *distance d'isolement* spécifiée.

Si un symbole est utilisé, les informations fournies par le *BDM/CDM/PDS* doivent contenir une explication du symbole et sa signification.

Les étiquettes doivent

a) lorsque c'est possible, utiliser les symboles internationaux donnés par l'ISO 3864-1, l'ISO 7000 ou l'IEC 60417,
b) être rédigées dans une langue appropriée ou dans une langue associée à un domaine technique particulier, si aucun symbole international n'est disponible,
c) être visibles, lisibles et durables,
d) être concises et non ambiguës, et
e) indiquer les dangers encourus ainsi que les moyens permettant de les réduire.

Lorsqu'il est indiqué aux personnes

f) ce qu'elles doivent éviter: il convient que la formulation emploie les termes "aucun(e)", "ne pas" ou "interdit";
g) ce qu'elles doivent faire: il convient que la formulation comporte les termes "doit" ou "est nécessaire de";
h) la nature du danger: il convient que la formulation comporte les termes "prudence", "avertissement" ou "danger", selon le cas;
i) la nature de conditions sûres: il convient que la formulation comporte le nom adapté au dispositif de sécurité.

Les panneaux de sécurité doivent être conformes à l'ISO 3864-1, sauf que d'autres combinaisons de couleurs, y compris monochrome, satisfaisant aux exigences de contraste de l'ISO 3864-4:2011, Article D.2, peuvent être utilisées. Pour des recommandations relatives à la détermination du contraste, voir l'Article C.2.

Les mots indicateurs définis ci-après doivent être utilisés et la hiérarchie suivante doit être respectée:

j) "DANGER" indique une situation dangereuse qui, si elle n'est pas évitée, va provoquer la mort ou de graves blessures, par exemple: "Haute tension".
k) "AVERTISSEMENT" indique une situation dangereuse qui, si elle n'est pas évitée, peut provoquer la mort ou de graves blessures, par exemple: "Cette surface peut être brûlante."
l) "PRUDENCE" indique une situation dangereuse qui, si elle n'est pas évitée, peut provoquer des blessures mineures ou modérées, par exemple: "Certains des essais spécifiés dans le présent document impliquent l'utilisation de procédés entraînant des risques pour les personnes concernées."

La hiérarchie de mots indicateurs doit être respectée au moins. Par exemple, "Danger" peut être utilisé en lieu et place de "Avertissement" ou "Prudence", mais pas l'inverse.

Les marquages de danger, d'avertissement et de prudence apposés sur le *BDM/CDM/PDS* doivent être précédés du mot indicateur "DANGER", "AVERTISSEMENT" ou "PRUDENCE", selon le cas, en caractères d'au moins 3,2 mm de hauteur. La hauteur des autres caractères de ces marquages ne doit pas être inférieure à 1,6 mm.

Si le marquage de danger, d'avertissement et de prudence est placé sur une surface visible, dont la largeur et la longueur sont chacune supérieures ou égales à 20 cm, les mots indicateurs doivent être écrits en caractères d'au moins 5 mm de hauteur. La hauteur des autres caractères de ces marquages ne doit pas être inférieure à 2,5 mm.

Les marquages "Danger", "Avertissement" et "Prudence" ne doivent pas être placés uniquement sur une partie amovible, sauf si la dépose de la partie compromet le fonctionnement ou l'apparence du *BDM/CDM/PDS*.

NOTE L'ANSI Z535 (toutes les parties) peut s'avérer utile pour obtenir d'autres informations sur les marquages.

Les marquages "Danger", "Avertissement" et "Prudence" destinés à informer l'opérateur doivent être lisibles et visibles dans les conditions normales de fonctionnement du *BDM/CDM/PDS*.

Tous les marquages de sécurité, étiquettes, panneaux et signaux appliqués sur le produit doivent être évalués comme étant durables. Les matériaux et la méthode de fixation doivent être adaptés à la *durée de vie prévue* du produit lorsqu'il est soumis aux conditions d'environnement dans lesquelles son transport, son stockage, son installation et son fonctionnement sont prévus.

Les matériaux sont acceptables lorsqu'ils sont conformes à l'ISO 17398.

Pour les marquages selon les normes de sécurité nationales équivalentes, voir 4.13.1.

Les méthodes de marquages suivantes sont considérées comme conformes sans essai:

m) marquages moulés, emboutis, marqués au stylo, estampillés;
n) matériau dépoli, découpé au laser ou gravé fixé en permanence.

Les étiquettes de sécurité du produit doivent présenter une durée de vie prévue raisonnable avec une bonne stabilité de la couleur, une bonne lisibilité du panneau de sécurité et du symbole d'informations sur la sécurité et une bonne lisibilité du texte lorsqu'il est posé à une certaine distance d'affichage. Il convient que le choix des matériaux et de la méthode de fixation tienne compte de l'environnement prévisible d'utilisation et de la durée de vie prévue du produit.

La conformité peut être démontrée par l'*inspection visuelle* du 5.2.1 de la fiche technique.

6.4.3.2 Dispositif d'isolation et de déconnexion

Comme cela est exigé en 4.1 et en 4.2, lorsqu'un dispositif d'isolation n'est pas destiné à couper le courant de charge, l'avertissement suivant doit apparaître:

NE PAS OUVRIR EN CHARGE.

Les exigences suivantes s'appliquent à tout dispositif d'isolation qui n'isole pas de toutes les sources d'alimentation d'un *PDS*.

a) Si le dispositif d'isolation est monté dans une *enveloppe* de *BDM/CDM/PDS* dont la manette de commande peut être actionnée de l'extérieur, une étiquette d'avertissement doit être prévue à proximité de la manette de commande, indiquant que celle-ci ne permet pas de couper toutes les sources alimentant le *BDM/CDM/PDS*.
b) Lorsque le sectionneur d'un *circuit de commande* peut être confondu avec les sectionneurs d'un circuit de puissance en raison de la dimension ou de l'emplacement, une étiquette d'avertissement doit être prévue à proximité de la manette de commande du sectionneur du *circuit de commande*, indiquant qu'elle ne permet pas de couper toutes les sources alimentant le *BDM/CDM/PDS*.
c) Conformité aux exigences relatives aux *BDM/CDM/PDS* à plusieurs sources d'alimentation, voir 6.5.5.

6.4.4 Surface brûlante

Lorsque cela est exigé par 4.6.5.3 ou 5.2.4.13.1, le symbole de prudence IEC 60417-5041:2002-10 ou ISO 7010-W017:2011-05 (voir le Tableau C.1) doit être placé sur ou à côté des parties dépassant les limites de température de contact indiquées dans le Tableau 18.

6.4.5 Marquage des commandes et du dispositif

Comme cela est exigé en 4.3, le marquage de l'identification de chaque dispositif de commande ou indicateur et de chaque dispositif de protection contre les *surintensités* doit être apposé à proximité de l'entité.

Le marquage des dispositifs de protection contre les *surintensités* de rechange doit indiquer leurs caractéristiques de courant nominal et de durée, sauf pour les fusibles semiconducteurs. Lorsque cela s'avère impossible à réaliser sur le produit, les informations doivent être données sous forme picturale dans le manuel.

L'identification appropriée doit faire l'objet d'un marquage sur ou à proximité de chaque connecteur mobile.

Le marquage individuel des points d'essai doit comporter la référence du schéma des circuits.

La polarité des dispositifs polarisés doit faire l'objet d'un marquage à proximité du dispositif.

La référence du schéma et si possible la fonction doivent faire l'objet d'un marquage à proximité de chaque commande préréglée en un point qui soit clairement visible au moment du réglage.

6.4.6 Stabilité des *BDM/CDM/PDS* posés au sol

Comme cela est exigé en 4.12.5 pour les *BDM/CDM/PDS* librement posés au sol ou portatifs, des mesures ou des informations doivent être fournies dans les instructions d'installation pour empêcher toute instabilité physique, y compris l'inclinaison.

6.5 Informations complémentaires

6.5.1 Généralités

6.5.1.1 Généralités

Comme cela est exigé en 4.1, pour assurer que la maintenance du *BDM/CDM/PDS* peut être réalisée en toute sécurité, les marquages de sécurité doivent être tel que prévu en 6.5.1.2.

6.5.1.2 Date de fabrication

Comme cela est exigé en 4.1, la date de fabrication du *BDM/CDM/PDS* doit être marquée sur le produit avec le code de date ou le numéro de série à partir duquel la date de fabrication peut être déterminée.

6.5.1.3 Informations de sécurité

Le fabricant doit déterminer et donner des informations de sécurité dans les manuels d'installation et de maintenance, y compris, selon le cas, les suivantes:

a) procédures et programmes de maintenance préventive;
b) mesures de sécurité en cours de maintenance (par exemple l’utilisation de sectionneurs de terre pour les *BDM/CDM/PDS haute tension*);
c) emplacement des *parties actives dangereuses* qui peuvent être accessibles pendant la maintenance (par exemple lorsque des *capots* sont retirés);
d) procédures de réglage;
e) procédures de réparation et de remplacement des sous-ensembles et des *composants*;
f) instruction selon laquelle la maintenance et l'installation sont uniquement réalisées par des *personnes qualifiées*;
g) toute autre information utile.

NOTE 1 Ces informations peuvent être, de préférence, présentées sous forme de schémas.

NOTE 2 Un une liste d’outils spéciaux peut être fournie, le cas échéant.

6.5.2 Décharge de condensateurs

Si les exigences du 4.4.9 ou du 4.5.2.2 ne sont pas satisfaites, les symboles d'avertissement IEC 60417-6042:2010-11 ou ISO 7010-W012:2011-05 et IEC 60417-5416:2015-04 (voir le Tableau C.1) et une indication du temps de décharge minimal dans les conditions les plus défavorables (temps de décharge de 5 min, par exemple) ou

> "AVERTISSEMENT: Risque de choc électrique – Temps de décharge du condensateur X s"

doivent être placés selon 6.4.3.1, la barrière de protection du condensateur ou à proximité du ou des condensateurs concernés (en fonction de la construction). Le symbole doit être expliqué et le temps nécessaire à la décharge des condensateurs après la coupure de l'énergie du *BDM/CDM/PDS* doit figurer dans les manuels d'installation et de maintenance.

NOTE La valeur du temps de décharge déclarée par le fabricant peut couvrir une plage du *PDS* en tenant compte des tolérances correspondantes pour la plage complète du *PDS*.

6.5.3 Mode de fonctionnement spécial – Redémarrage automatique/connexion de dérivation

Comme cela est exigé en 4.1, si un *BDM/CDM/PDS* peut être configuré pour fournir un redémarrage automatique ou une connexion de dérivation, les manuels d'installation, d'utilisation et de maintenance doivent contenir les avertissements appropriés.

6.5.4 Autres dangers

Comme cela est exigé en 4.1 et en 4.2, le fabricant doit identifier (sur le produit et dans les manuels d'installation et de maintenance, selon le cas) tous les *composants* et matériaux d'un *BDM/CDM/PDS* qui exigent des procédures particulières afin d'éviter tous les dangers liés au produit.

Une étiquette de prudence ou d'avertissement appropriée doit être placée sur le produit selon le Tableau 48 et 6.4.3.1 en prenant en considération la nature du danger.

6.5.5 *BDM/CDM/PDS* à plusieurs sources d'alimentation

Conformément à 4.8, en présence de plusieurs sources d'alimentation du *BDM/CDM/PDS*, des informations doivent être fournies pour indiquer quel dispositif de déconnexion doit être utilisé pour isoler complètement le *BDM/BDM/PDS*.

Si plusieurs sectionneurs sont exigés pour déconnecter toutes les alimentations à l'intérieur d'un ensemble de contrôle-commande ou d'un compartiment, l'ensemble ou le compartiment doit être marqué selon 6.4.3.1 et 6.4.3.2 avec

a) les mots "Risque de choc électrique – Plusieurs sectionneurs sont exigés pour mettre l'équipement hors tension avant la procédure d'entretien.", ou un équivalent, et
b) le mot "AVERTISSEMENT ", ou
c) le symbole d'avertissement IEC 60417-6042:2010-11 ou ISO 7010-W012:2011-05 (voir le Tableau C.1).

NOTE Au Canada, le texte suivant doit être utilisé:

> AVERTISSEMENT: PLUSIEURS CIRCUITS SOUS TENSION. VOIR LE SCHÉMA.

Le marquage doit être dans le manuel d'installation et

d) apposé à demeure à l'extérieur du *BDM/CDM/PDS*, ou
e) sur une partie fixe stationnaire non amovible à l'intérieur du *BDM/CDM/PDS*.

6.5.6 Connexion TP/TI

Comme cela est exigé en 4.1 et en 4.2, dans le cas d'un *BDM/CDM/PDS* comportant un transformateur de potentiel (PT) alimenté à haute tension ou un transformateur de courant (CT) alimenté par une connexion de courant élevé pour les fonctions de surveillance et de commande externes, le produit doit comporter un marquage indiquant clairement les dangers potentiels de tensions transitoires dues à une déconnexion du circuit secondaire. Les dangers doivent également être décrits dans les manuels d'installation et de maintenance.

6.5.7 Conditions d'accès au *PDS/CDM/PDS haute tension* pendant la maintenance

NOTE Dispositifs d'isolement d'après l'UL 347A.

Un commutateur qui peut être mis sous tension à partir d'un côté doit porter le marquage

"DANGER – Les couteaux de contact peuvent être actifs au moment de l'ouverture."

Ce marquage doit être étendu pour inclure une référence aux fusibles et aux porte-fusibles, le cas échéant. Voir 4.4.10.2.1.5.

Un *BDM/CDM/PDS* sans dispositif d'isolation intégral tel qu'indiqué en 4.4.10.2 doit être marqué comme suit.

a) "DANGER. Cet équipement n'assure pas l'isolation. Séparation des dispositifs d'isolation exigée. Voir les instructions pour plus d'informations." Le marquage doit également inclure une référence au manuel d'instruction spécifique contenant ces informations par numéro de publication, numéro de dessin, ou un équivalent.
b) Les instructions référencées dans le marquage doivent indiquer les dispositifs d'isolation externes spécifiques qui doivent être fournis, le cas échéant.
c) Si le *système de verrouillage* n'est pas fourni, les instructions doivent identifier le kit de *verrouillage* par numéro de fabricant ou de catalogue qui doit être installé sur les dispositifs d'isolation externes afin de coordonner le *système de verrouillage* du *BDM/CDM/PDS* avec les dispositifs d'isolation. Le kit doit inclure des instructions spécifiques détaillant l'installation du *verrouillage* sur les dispositifs d'isolation.

Le manuel d'installation et de maintenance doit préciser les exigences relatives aux sectionneurs de terre et/ou au *conducteur de mise à la terre de protection* amovible du *BDM/CDM/PDS* pendant la maintenance.

Annex A
(normative)

Informations supplémentaires relatives à la protection contre les chocs électriques

A.1 Généralités

L'Article A.2, l'Article A.3 et l'Article A.4 donnent des exemples de méthodes utilisées pour assurer la protection contre les chocs électriques dans les *BDM/CDM/PDS* relevant de la classe de protection *III* et dans les circuits *CTD As* (voir 4.4.2.2).

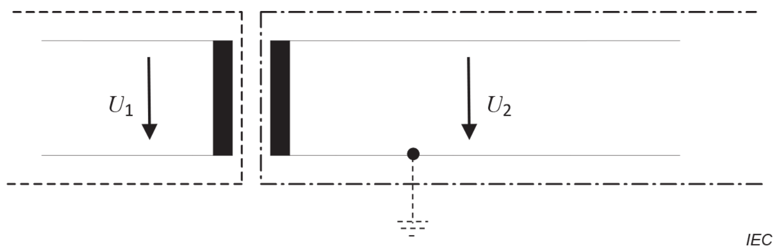
La légende suivante s'applique de la Figure A.1 à la Figure A.3.

-------------------- *Protection principale*

—·—·—·—·—·—·—·—·— *Protection renforcée* des *circuits adjacents* selon le Tableau 3

A.2 Protection au moyen de la *CTD* As

(voir 4.4.2.2)



Légende

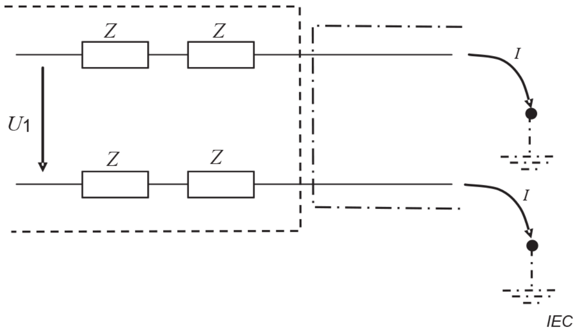
U_1 tension dangereuse, mise ou non à la terre

U_2 ≤ *CTD As* du Tableau 2

Figure A.1 – Protection par la *CTD As* avec *protection renforcée*

A.3 Protection au moyen d'*impédances de protection*

(voir 4.4.5.4)



Légende

Z résistance

U_1 tension dangereuse, mise ou non à la terre

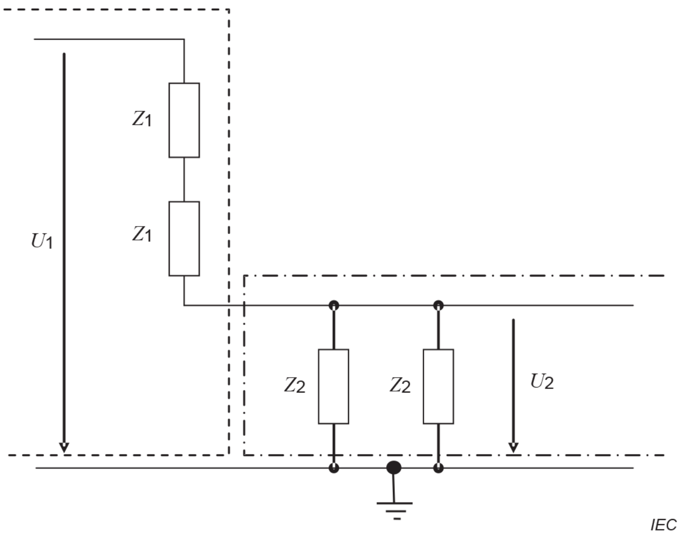
I ≤ limites du 4.4.5.4

Pour assurer la protection dans les *conditions de premier défaut*, utiliser la formule suivante: $I = \frac{U_1}{Z}$

Figure A.2 – Protection au moyen *d'impédances de protection*

A.4 Protection au moyen de tensions limitées

(voir 4.4.5.4)



Légende

Z résistance

U_1 tension dangereuse, mise à la terre

U_2 ≤ *CTD As* du Tableau 2.

Pour assurer la protection dans les *conditions de premier défaut*, utiliser les formules suivantes:

$$U_2 = \frac{U_1 Z_2}{2Z_1 + Z_2} \quad \text{ou} \quad U_2 = \frac{U_1 Z_2}{2(Z_1 + Z_2/2)}$$

Figure A.3 – Protection au moyen de tensions limitées

A.5 Évaluation de la *tension de fonctionnement* des circuits

A.5.1 Généralités

La tension déterminante de chaque circuit du *BDM/CDM/PDS* en ce qui concerne les mesures de protection à utiliser contre les chocs électriques, est la tension la plus élevée qui se produit entre deux *parties actives* aléatoires à l'intérieur de ce circuit dans les conditions de fonctionnement assignées les plus défavorables dans le cadre de l'utilisation prévue.

Si la connexion du circuit à la *terre de protection* est fournie, la tension déterminante est la tension la plus élevée qui se produit entre une *partie active* aléatoire de ce circuit et la terre (les circuits connectés à une alimentation triphasée reliée à la terre, par exemple).

Une partie du circuit *CTD As* peut dépasser les limites de tension du Tableau 2 lorsque ladite partie est protégée contre le contact direct selon 4.4.3.3 et que la partie accessible du circuit *CTD As* respecte les limites de tension du Tableau 2 dans les *conditions de premier défaut* selon 4.2. Ces tensions doivent néanmoins toujours être utilisées dans la détermination des *distances d'isolement* et des *lignes de fuite* pour le circuit à l'étude par rapport à son *environnement* en 4.4.7.4 et en 4.4.7.5.

A.5.2 Classification de la *tension de fonctionnement*

Les limites du Tableau 2 sont valables pour le courant alternatif pratiquement sinusoïdal et le courant continu pratiquement sans ondulation. Toutefois, dans les circuits électroniques de conversion de puissance, les formes de courbe des tensions sont présentes et ne sont ni en courant alternatif pratiquement sinusoïdal ni en courant continu pratiquement sans ondulation.

Le paragraphe A.5.2 donne les méthodes et règles de classement des formes de tension dans l'une des *CTD* du Tableau 2.

La première étape détermine la valeur moyenne de la tension à l'étude: si la valeur moyenne est égale à zéro, cette tension est considérée comme une *tension de fonctionnement* en courant alternatif et les règles sont données en A.5.3.

NOTE Le terme "zéro" utilisé ci-dessus signifie une valeur moyenne négligeable.

Si la valeur moyenne est différente de zéro dans la deuxième étape, la valeur efficace de la tension d'ondulation superposée est déterminée.

- Si cette valeur efficace de l'ondulation ne dépasse pas 10 % de la valeur moyenne du courant continu, cette tension est considérée comme la *tension de fonctionnement* en courant continu, et les règles sont données en A.5.4.
- Si cette valeur efficace de l'ondulation dépasse 10 % de la valeur moyenne du courant continu, cette tension est considérée comme la *tension de fonctionnement* pulsatoire, et les règles sont données en A.5.5.

Dans la troisième étape, la méthode définie en A.5.2 permet de déterminer les valeurs applicables de

- valeur efficace courant alternatif (U_{AC}),
- crête répétitive en courant alternatif (U_{ACP}),
- moyenne en courant continu (U_{DC}), et
- crête répétitive en courant continu (U_{DCP}).

La Figure A.4, la Figure A.5 et la Figure A.6 présentent des formes d'onde classiques pour l'évaluation de la *tension de fonctionnement*.

A.5.3 *Tension de fonctionnement* en courant alternatif

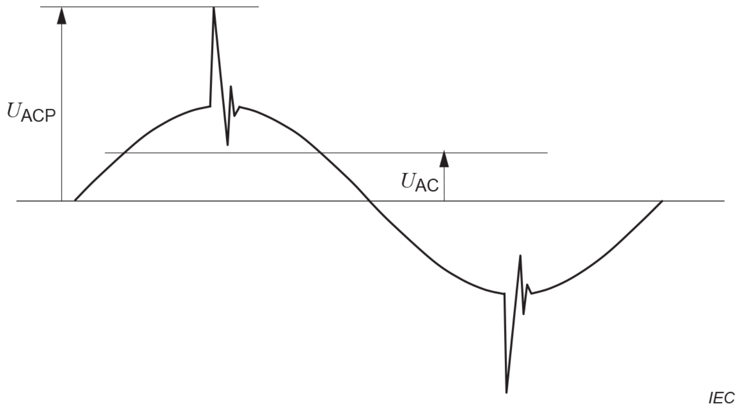


Figure A.4 – Forme d'onde classique d'une *tension de fonctionnement* en courant alternatif

La *tension de fonctionnement* possède une valeur efficace U_{AC} et une valeur de crête répétitive U_{ACP}.

La *CTD* est celle de la ligne de tension la plus basse du Tableau 2 en commençant par la *CTD As* pour laquelle les deux conditions suivantes sont satisfaites pour la même ligne:

- $U_{AC} \leq U_{ACL}$;
- $U_{ACP} \leq U_{ACPL}$.

Exemple avec des valeurs:

U_{AC} = 39 V --> est inférieur à U_{ACL} = 50 V --> CTD B

U_{ACP} = 91 V --> est supérieur à U_{ACPL} = 71 V --> CTD C

La règle de détermination de la *CTD* de la tension consiste à choisir la *CTD* la plus élevée.

Résultat: --> cette *tension de fonctionnement* est *CTD C*.

A.5.4 *Tension de fonctionnement* en courant continu

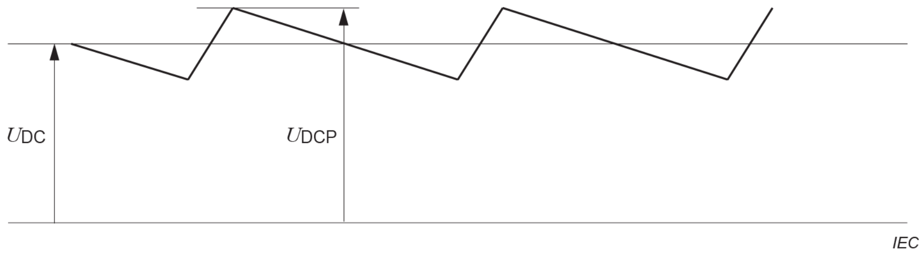


Figure A.5 – Forme d'onde classique d'une *tension de fonctionnement* en courant continu

La *tension de fonctionnement* possède une valeur moyenne U_{DC} et une valeur de crête répétitive U_{DCP}.

La *CTD* est celle de la ligne de *CTD* du Tableau 2 commençant par la *CTD As* pour laquelle les deux conditions suivantes sont satisfaites pour la même ligne:

- $U_{DC} \leq U_{DCL}$;
- $U_{DCP} \leq 1{,}17 \times U_{DCL}$.

NOTE La valeur de 1,17 résulte d'une tension d'ondulation superposée sur une forme d'onde en triangle avec une valeur efficace de 10 %.

Exemple avec des valeurs:

U_{DC} = 39 V	-->	est inférieur à U_{DCL} = 60 V	-->	*CTD As sec*
U_{DCP} = 69 V	-->	est inférieur à 1,17 × U_{DCL} = 70,2 V	-->	*CTD As sec*

La règle de détermination de la *CTD* de la tension consiste à choisir la *CTD* la plus élevée.

Résultat: --> cette *tension de fonctionnement* est *CTD As sec*.

A.5.5 *Tension de fonctionnement* pulsatoire

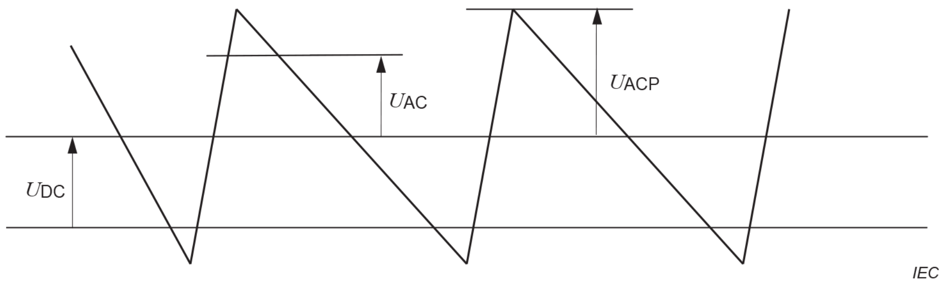


Figure A.6 – Forme d'onde classique d'une *tension de fonctionnement* pulsatoire

La *tension de fonctionnement* possède une valeur moyenne U_{DC}, une valeur en courant alternatif U_{AC} et une valeur de crête répétitive U_{ACP}.

La *CTD* est celle de la ligne de *CTD* du Tableau 2 commençant par la *CTD As* pour laquelle les deux conditions suivantes sont satisfaites pour la même ligne:

$$\frac{U_{AC}}{U_{ACL}} + \frac{U_{DC}}{U_{DCL}} \leq 1 \quad \text{et} \quad \frac{U_{ACP}}{U_{ACPL}} + \frac{U_{DC}}{1{,}17 \times U_{DCL}} \leq 1$$

Exemple avec des valeurs:

U_{DC} = 39 V;

U_{AC} = 49 V;

U_{ACP} = 91 V.

Premier calcul avec les limites de la *CTD B:*

$$\frac{49}{50} + \frac{39}{120} \leq 1 \ ?$$

0,980 + 0,325 = 1,305 --> le résultat dépasse 1 --> *CTD C*

et

$$\frac{91}{71}+\frac{39}{1{,}17\times 120}\leq 1\ ?$$

1,282 + 0,278 = 1,560 --> le résultat dépasse 1 --> *CTD C*

La règle de détermination de la *CTD* de la tension consiste à choisir la *CTD* la plus élevée:

Résultat: --> cette *tension de fonctionnement* est *CTD C*.

A.6 Concept de mesure de protection selon 4.4

A.6.1 Généralités

La protection contre les chocs électriques doit être assurée au moyen

- d'une combinaison de *protection principale* selon 4.4.3 et d'une *protection en cas de défaut* selon 4.4.4, ou
- d'une *protection renforcée* selon 4.4.5.

Les cas décrits en A.6.2 et en A.6.3 concernent la protection des *personnes ordinaires*. La protection des *personnes qualifiées* permet une protection réduite selon 4.4.3.3.3.

De plus, seule la protection des circuits *CTD As* par rapport à la *CTD C* et la *CTD D* est couverte.

A.6.2 Concept général de protection contre les chocs électriques

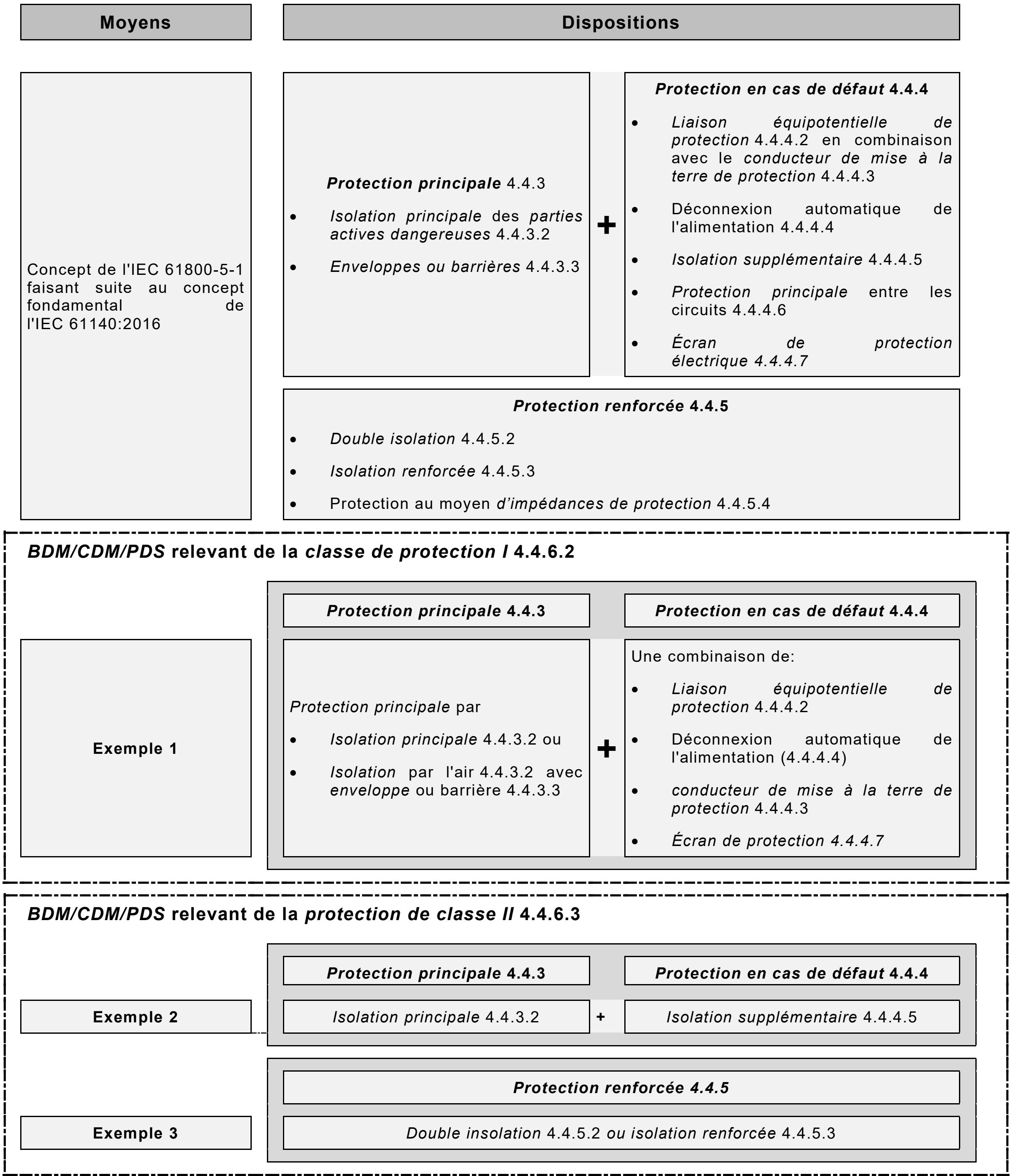


Figure A.7 – Mesures de protection selon les paragraphes 4.4.1 à 4.4.5 pour la protection contre les *chocs électriques* en prenant en considération les *BDM/CDM/PDS* relevant de la *classe de protection I* et de la *classe protection II*

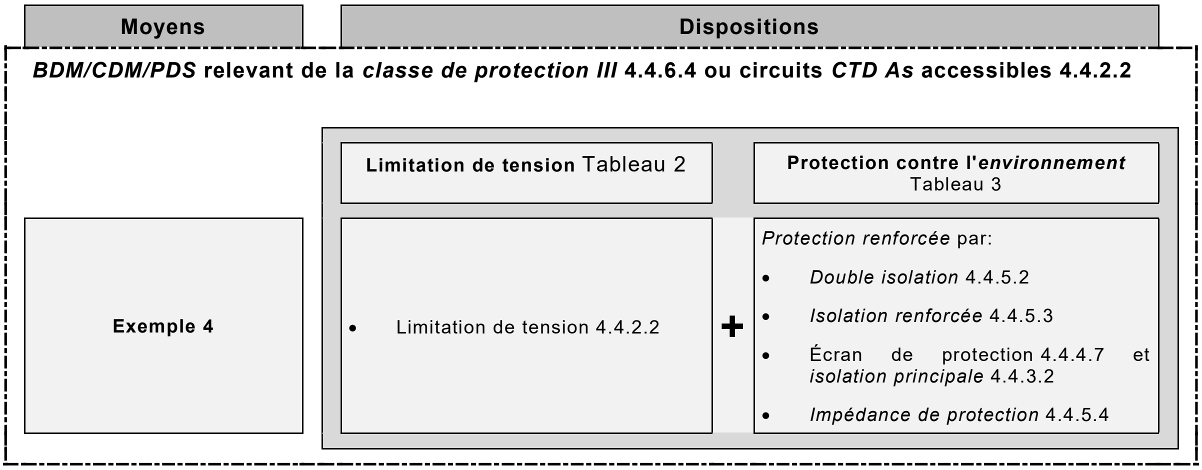


Figure A.8 – Mesures de protection selon les paragraphes 4.4.1 à 4.4.5 pour la protection contre les *chocs électriques* en prenant en considération les *BDM/CDM/PDS* et circuits *CTD As* relevant de la *classe protection III*

A.6.3 Exemples d'utilisation d'éléments de mesures de protection

Le Tableau A.1 donne les exigences relatives aux ouvertures d'*enveloppe* ou de barrière dans la ligne 4 et la ligne 5 (voir 4.4.3.3). Il donne également des exemples d'*isolation* entre les *parties accessibles* et les *parties actives dangereuses* de la ligne 1, de la ligne 2 et de la ligne 3.

Le niveau d'*isolation* exigé dépend

- de la *CTD* des *parties actives dangereuses* selon le Tableau 2,
- des exigences d'*isolation* entre les *circuits adjacents* selon le Tableau 3,
- du raccordement des *parties accessibles conductrices* à la terre par la *liaison équipotentielle de protection* selon 4.4.4.2, et
- des *parties accessibles* non conductrices.

À la place de l'*isolation solide*, une *distance d'isolement* selon 4.4.7.4, représentée par L_1 et L_2 dans le Tableau A.1 peut être fournie.

Dans le Tableau A.1, trois cas sont considérés.

Cas a) – Les *parties accessibles* sont conductrices et raccordées à la terre par la *liaison équipotentielle de protection*.

Sans *circuit adjacent*:

- Cellules 1a, 2a, 4a: La *protection principale* est exigée entre les *parties accessibles* et les *parties actives dangereuses*. La tension correspondante est celle des *parties actives dangereuses*.
- Cellule 5a: La *protection renforcée* est exigée entre les *parties accessibles* et les *parties actives dangereuses* de la *CTD D*. La tension correspondante est celle des *parties actives dangereuses*.

Avec *circuit adjacent*:

- Cellule 3a – ligne supérieure: *Protection principale* entre les *parties accessibles* et les *parties actives dangereuses* des circuits de la *CTD B,* CTD *C* ou *CTD D* qui sont séparées des *circuits adjacents* de la *CTD B, CTD C ou CTD D* par la *protection principale.* La tension correspondante est celle de la *partie active dangereuse* avec la tension supérieure*.*
- Cellule 3a – ligne inférieure: *Protection principale* entre les *parties accessibles* et les *parties actives dangereuses* des circuits de la *CTD B* ou *CTD C* qui présentent une *protection renforcée* des *circuits adjacents* de la *CTD C* ou *CTD D*. La tension correspondante est celle des *parties actives dangereuses.*

Cas b) et c):

Les *parties accessibles* ne sont pas conductrices (cas b) ou conductrices mais non raccordées à la terre par la *liaison équipotentielle de protection* (cas c). La *protection* exigée est comme suit.

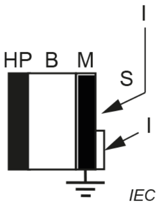
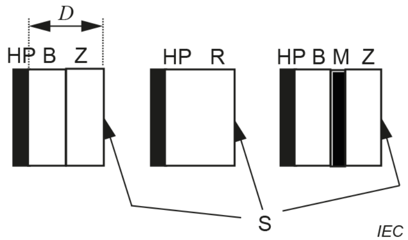
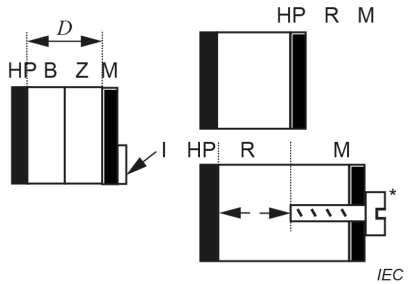
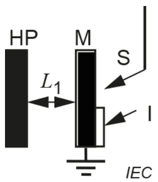
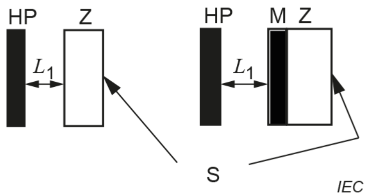
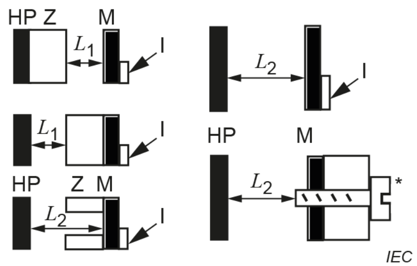
Sans *circuit adjacent*: Cellules 1b, 1c, 2b, 2c, 4b, 4c, 5b et 5c: P*rotection renforcée* entre les *parties accessibles* et les *parties actives dangereuses* de la *CTD C* ou *CTD D*. La tension correspondante est celle des *parties actives dangereuses*.

Avec *circuit adjacent*:

- Cellules 3b – ligne supérieure, 3c – ligne supérieure: *Protection en cas de défaut* entre les *parties accessibles* et les *parties actives dangereuses* des circuits de la *CTD* C séparées par une *protection principale* des *circuits adjacents* de la *CTD* C. La tension correspondante est la tension la plus élevée des *circuits adjacents*. Cela équivaut à l'exigence relative à la *protection renforcée* entre le circuit AC et le circuit HP et couvre les exigences de *protection principale* entre la surface accessible et le circuit HP.
- Cellules 3b – ligne inférieure, 3c – ligne inférieure: *Protection principale* entre les *parties accessibles* et les *parties actives dangereuses* des circuits de la *CTD C* qui présentent une *protection renforcée* des *circuits adjacents* de la *CTD C* ou *CTD D*. La tension correspondante est celle des *parties actives dangereuses*.

Le Tableau A.1 ne présente pas les exigences d'*isolation* pour la *CTD As* et la *CTD B.*

Tableau A.1 – Configurations de la protection contre les chocs électriques

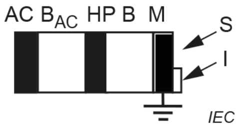
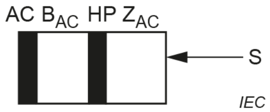
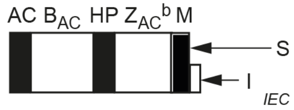
Type d'isolation	**Configuration de l'isolation**		
	a	**b**	**c**
	Les p*arties accessibles* conductrices sont raccordées à la terre par la *liaison équipotentielle de protection*	**Parties accessibles non conductrices**	***Parties accessibles* conductrices, mais <u>NON</u> raccordées à la terre par la *liaison équipotentielle de protection***
1. Solid			
2. Totalement ou partiellement par *distance d'isolement*			

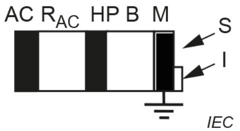
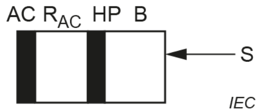
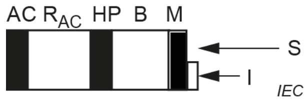
<table>
<tr><th rowspan="2">Type d’isolation</th><th colspan="3">Configuration de l'isolation</th></tr>
<tr><th>a</th><th>b</th><th>c</th></tr>
<tr><td></td><td>Les parties accessibles conductrices sont raccordées à la terre par la liaison équipotentielle de protection</td><td>Parties accessibles non conductrices</td><td>Parties accessibles conductrices, mais <u>NON</u> raccordées à la terre par la liaison équipotentielle de protection</td></tr>
<tr><td>3. Isolation pour les circuits adjacents:

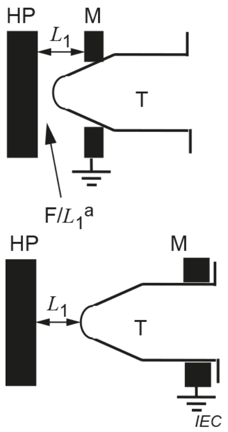
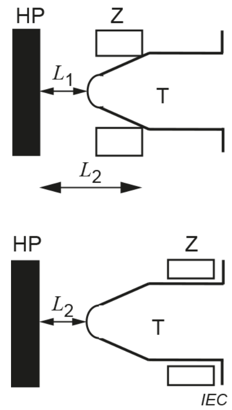
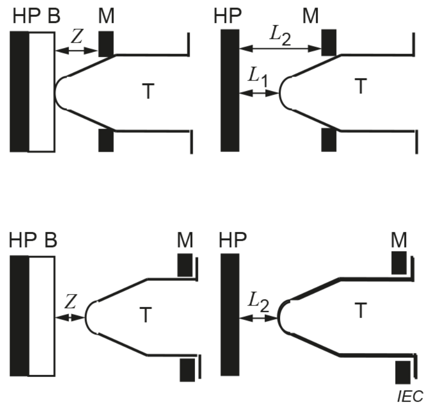
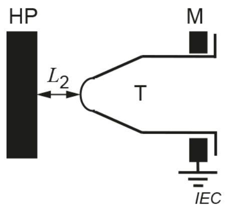
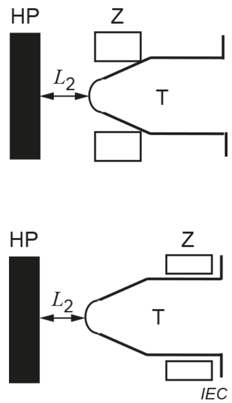
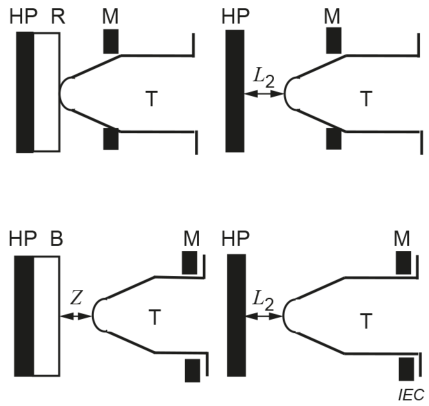
Circuit HP: circuit de tension inférieure;

Circuit AC: circuit de tension supérieure;

ligne supérieure –

Courant alternatif: CTD C uniquement,</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>ligne inférieure –

AC: CTD C ou CTD D</td><td>
</td><td>
</td><td>
</td></tr>
</table>

<table>
<tr><th rowspan="2">Type d'isolation</th><th colspan="3">Configuration de l'isolation</th></tr>
<tr><th>a</th><th>b</th><th>c</th></tr>
<tr><td></td><td>Les parties accessibles conductrices sont raccordées à la terre par la liaison équipotentielle de protection</td><td>Parties accessibles non conductrices</td><td>Parties accessibles conductrices, mais <u>NON</u> raccordées à la terre par la liaison équipotentielle de protection</td></tr>
<tr><td>4. Exigences relatives aux ouvertures dans les enveloppes
Circuit HP: CTD C</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>5. Exigences relatives aux ouvertures dans les enveloppes
Circuit HP: CTD D</td><td>
</td><td>
</td><td>
</td></tr>
</table>

Type d'isolation	**Configuration de l'isolation**		
	a	**b**	**c**
	Les p*arties accessibles* conductrices sont raccordées à la terre par la *liaison équipotentielle de protection*	**Parties accessibles non conductrices**	***Parties accessibles* conductrices, mais <u>NON</u> raccordées à la terre par la *liaison équipotentielle de protection***

HP *hazardous live part (partie active dangereuse)*	L_1 *distance d'isolement* pour l'*isolation principale*	T doigt d'essai (calibre d'essai de la Figure M.2)
B *basic insulation* for circuit HP (*isolation principale* pour circuit HP)	L_2 *distance d'isolement* pour l'*isolation renforcée*	Z *isolation supplémentaire* pour circuit HP
B_{AC} *basic insulation* for circuit AC (*isolation principale* pour *circuit adjacent*)	M partie conductrice	Z_{AC} *isolation supplémentaire* pour circuit AC
AC *adjacent circuit* (*circuit adjacent*)	R *isolation renforcée* pour circuit HP	* s'applique aussi aux vis en plastique
D *double insulation* for circuit HP (*double isolation* pour circuit HP)	R_{AC} *isolation renforcée* pour circuit AC	F *isolation fonctionnelle* pour circuit HP
I *isolation* facultative inférieure à B pour d'autres besoins que la protection contre les chocs électriques	S surface du *BDM/CDM/PDS*	

NOTE 1 À la colonne c), une vis en plastique est considérée comme métallique parce qu'un utilisateur peut la remplacer par une métallique au cours de la vie du *BDM/CDM/PDS*.

NOTE 2 À la ligne 4, l'insertion du doigt d'essai est considérée comme représentant une situation de premier défaut (pour plus d'informations, voir également l'IEC 60730-1, l'IEC 60335-1 et l'IEC 62368-1).

[a] *L'isolation fonctionnelle* est suffisante si l'ouverture est couverte pendant le fonctionnement normal. Il ne doit pas être possible de retirer le *capot* sans utiliser d'outil ou de clé. Si l'ouverture n'est pas couverte pendant le fonctionnement normal, l'*isolation principale* est exigée.

[b] En ce qui concerne l'exigence d'*isolation* Z_{AC} du *circuit adjacent* AC de la ligne 3a, 3b et 3c, l'exigence d'*isolation* du circuit HP de la ligne 1 et de la ligne 2 doit l'être également. L'exigence de protection doit être supérieure à l'exigence pour HP (*isolation renforcée* de HP) de la ligne 1 ou de la ligne 2 et à l'exigence pour AC (*isolation supplémentaire* d'AC) de la ligne 3.

Annex B
(informative)

Considérations relatives à la réduction du degré de pollution

B.1 Généralités

L'Annex B a pour objet de donner un aperçu des facteurs qu'il convient de prendre en considération pour réduire le degré de pollution d'un équipement électrique afin de réduire les *distances d'isolement* et les *lignes de fuite*. Les mesures à prendre dépendant largement de la nature de la pollution, aucune recommandation exhaustive ne peut être donnée quant à la manière d'atteindre l'objectif d'un degré de pollution inférieur pour l'équipement.

B.2 Facteurs ayant un impact sur le degré de pollution

Les facteurs suivants ont un impact sur le degré de pollution.

- Pollution
  - pas de pollution;
  - pollution non conductrice sèche;
  - pollution non conductrice sèche; qui peut devenir conductrice, avec l'humidité;
  - pollution conductrice.

NOTE La pollution peut être extérieure ou peut être générée en interne ou présente en interne à l'issue de la fabrication.

- Humidité
  - pas ou peu d'humidité sans condensation;
  - condensation temporaire;
  - humidité permanente;
  - pluie ou neige.

B.3 Réduction des facteurs d'influence

Certaines mesures qui peuvent être appliquées pour réduire les facteurs d'influence sont présentées ci-dessous. Les mesures décrites pour satisfaire aux exigences sont données à titre d'illustration uniquement. Il peut y avoir d'autres possibilités.

- revêtement ou empotage (voir 4.4.7.6);
- IP5X (essai de poussière selon l'IEC 60529);
- IPX4 à IPX8 en fonction de l'environnement.

Lors de la fermeture hermétique d'un équipement électrique, il convient d'assurer que le niveau d'humidité est au niveau bas exigé lors de la refermeture de l'équipement après avoir ouvert l'*enveloppe* (pour l'entretien, par exemple).

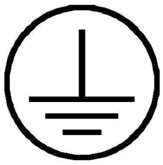
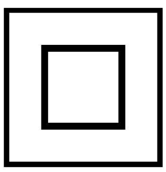
Annex C
(informative)

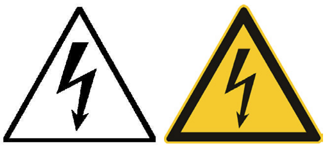
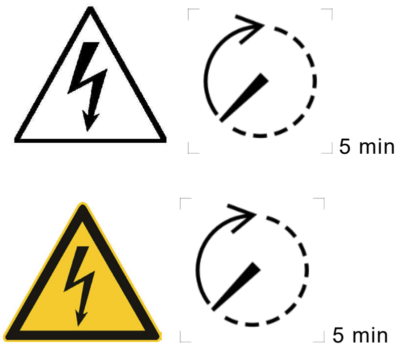
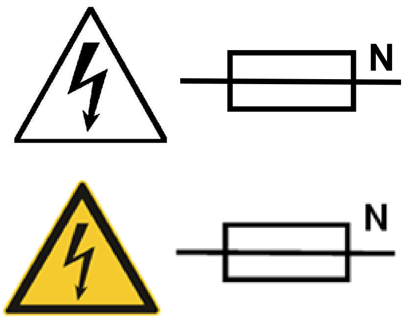
Symboles référencés

C.1 Symboles utilisés

Un aperçu des symboles utilisés dans le présent document est donné dans le Tableau C.1.

Tableau C.1 – Symboles utilisés

Symbole	Références normatives	Description	Paragraphe
	IEC 60417-5019:2006-08	Borne de conducteur de mise à la terre de protection (borne de *conducteur de mise à la terre de protection*) *Classe de protection I*	4.4.4.2.1, 4.4.4.3.2, 6.3.9.2.2
	IEC 60417-5017:2006-08	Borne de *conducteur de mise à la terre de protection*	4.4.4.3.2, 6.3.9.2.2
	IEC 60417-5018:2011-07	Borne de mise à la terre fonctionnelle	4.4.6.3 6.3.9.2.3
  	ISO 7010-W001:2011-05 ou ISO 7000-0434a:2004-01 ou ISO 7000-0434b:2004-01	Avertissement, voir la documentation	4.4.4.3.3, 4.4.8, 4.8, 4.11.11.3, 6.3.7.5, 6.3.9.4, 6.5.7, P.5
	IEC 60417-5172:2003-02	*BDM/CDM/PDS* relevant de la *casse de protection II* (*double insolation*)	4.4.6.3 6.3.9.2.3
	IEC 60417-5180:2003-02	*BDM/CDM/PDS relevant de la classe de protection III*	4.4.6.4, 6.3.9.2.4

Symbole	Références normatives	Description	Paragraphe
	IEC 60417-6042:2010-11 ou ISO 7010-W012:2011-05	Avertissement, risque de choc électrique	4.4.9, 4.8, 6.5.7
	IEC 60417-5041:2002-10 ou ISO 7010-W017:2011-05	Prudence, surface brûlante	4.6.5.3, 6.4.4
	IEC 60417-6042:2010-11 ou ISO 7010-W012:2011-05 et IEC 60417-5416:2015-04 et indication du temps	Avertissement, risque de choc électrique Affichage du temps restant; traitement (temps de décharge du condensateur)	4.4.9, 6.5.2
	IEC 60417-6042:2010-11 ou ISO 7010-W012:2011-05 et et une indication que le fusible est au neutre N	Prudence, fusion double pôle/neutre	4.3.4, 6.2
	ISO 7010-M002:2011-05	Voir le manuel/livret d'instructions (voir les manuels d'instruction, d'installation, d'utilisation et/ou de maintenance)	6.1, 6.1.3

C.2 Détermination du contraste

Si le système de couleur de l'ISO 7010 pour les signaux de sécurité et d'avertissement n'est pas utilisé, le contraste relatif peut être calculé à l'aide de la valeur de réflectance de lumière (LRV – *light reflectance value*) de chaque couleur d'arrière-plan et de texte/symbole à l'aide de la formule de l'ISO 21542:2011[4]:

$$C = 100 \times \frac{LRV_1 - LRV_2}{LRV_1}$$

où

LRV_1 est la LRV de la couleur la plus claire;

LRV_2 est la LRV de la couleur la plus sombre.

NOTE 1 L'équation ci-dessus est l'équation du contraste de Weber.

Un contraste visuel acceptable est obtenu si

- la couleur la plus claire présente un LRV d'au moins 40, et
- le contraste relatif est d'au moins 80 %.

NOTE 2 La LRV de 40 pour la couleur la plus claire est une approximation du RAL 1003[5] (signal jaune) comme l'exige d'ISO 3864-4:2011, qui présente une LRV d'environ 48.

NOTE 3 L'exigence de contraste relatif est issue de la recommandation de l'ISO 3864-4:2011, Article D.2.

EXEMPLE 1

Blanc (RAL 9010, blanc pur): LRV_1 = 84

Noir (RAL 9004, noir de signal): LRV_2 = 2

Contraste relatif = ((84 – 2) / 84) = 98 %

EXEMPLE 2

Jaune (RAL 1003, jaune de signal): LRV_1 = 48

Noir (RAL 9004, noir de signal): LRV_2 = 2

Contraste relatif = ((48 – 2) / 48) = 96 %

EXEMPLE 3

Bleu (RAL 5012, bleu de signal): LRV_1 = 21

Blanc (RAL 9010, blanc pur): LRV_1 = 84

Contraste relatif = ((84 – 21) / 84) = 75 %

NOTE 4 Un autre *système* que RAL peut être également adapté, à condition que les valeurs de réflexion claire soient mesurées dans le même *système*. De même, dans le *système* RAL, les valeurs de réflexion claire peuvent être sensiblement différentes en fonction de la source utilisée.

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[4] Cette publication a été retirée.

[5] RAL est un exemple de *système* de classement des couleurs disponible dans le commerce. Cette information est donnée à l'intention des utilisateurs du présent document et ne signifie nullement que l'IEC approuve ou recommande l'emploi exclusif du produit cité.

Annex D
(normative)

Évaluation des *distances d'isolement* et des *lignes de fuite*

D.1 Mesurage

Les *distances d'isolement* et les *lignes de fuite* doivent être évaluées comme cela est représenté dans les exemples de la Figure D.1 à la Figure D.15.

Pour les chemins composés de parties présentant différents degrés de pollution (lors de l'intégration d'un joint scellé qui assure une protection de type 1 (IEC 60664-3), par exemple) dans un environnement de degré de pollution 2, les *distances d'isolement* et les *lignes de fuite* sont déterminées selon le Tableau 8 et le Tableau 10, à l'aide de formules suivantes.

- En règle générale, une *ligne de fuite* peut être divisée en plusieurs parties de différents matériaux et/ou présenter différents degrés de pollution si l'une des *lignes de fuite* est dimensionnée de manière à résister à la tension totale ou si la distance totale est dimensionnée en fonction du matériau dont l'IRC est le plus bas et le degré de pollution le plus élevé.
- Pour les *lignes de fuite* pour l'*isolation fonctionnelle* sur carte de circuit imprimé et des *composants* assemblés sur carte de circuit imprimé, conçues pour un degré de pollution 1 et 2, la somme des tensions déterminantes de chaque partie du chemin ne doit pas être inférieure à la tension déterminante des circuits concernés. Les distances pour chaque partie de la *ligne de fuite* à l'étude doivent satisfaire aux distances minimales selon le Tableau D.1.

D.2 Relation entre le mesurage et le degré de pollution

Les valeurs "X" dépendent du degré de pollution et doivent être telles que spécifiées dans le Tableau D.1. Si la *distance d'isolement* exigée associée est inférieure à 3 mm, la valeur X est égale à un tiers de la *distance d'isolement*.

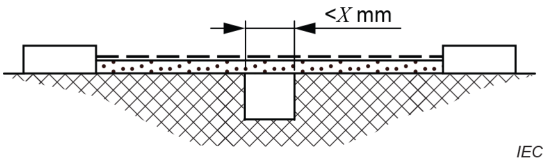
Tableau D.1 – Largeur des rainures en fonction du degré de pollution

Degré de pollution	valeur X mm
1	0,25
2	1,0
3	1,5

D.3 Exemples

Dans les exemples représentés de la Figure D.1 à la Figure D.14 ci-dessous, les *distances d'isolement* et les *lignes de fuite* sont différenciées comme suit:

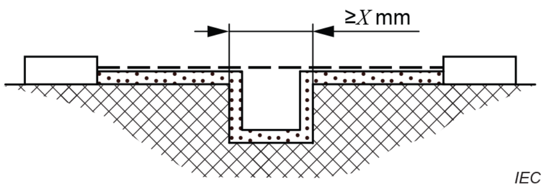
Distance dans l'air Ligne de fuite



Condition: Le chemin à l'étude comporte une rainure à côté parallèle, divergente ou convergente, d'une profondeur quelconque avec une largeur inférieure à X mm.

Règle: La *ligne de fuite* et la *distance d'isolement* sont mesurées directement à travers la rainure comme cela est représenté.

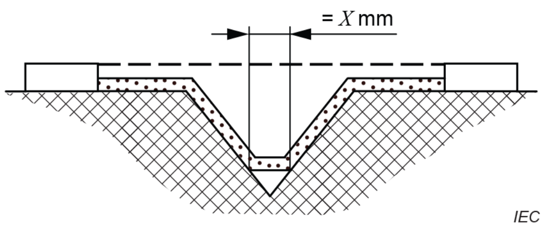
Figure D.1 – Exemple de mesurage incluant une rainure



Condition: Le chemin à l'étude comporte une rainure à côté parallèle ou divergente d'une profondeur quelconque avec une largeur supérieure ou égale à X mm.

Règle: La *distance d'isolement* est la distance de "visibilité". Le chemin de la *ligne de fuite* suit le contour de la rainure.

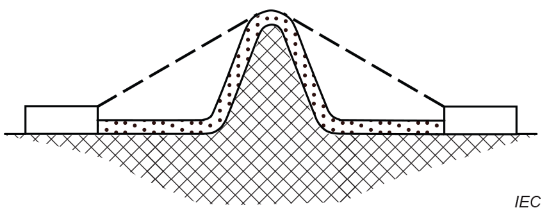
Figure D.2 – Exemple de mesurage incluant une rainure



Condition: Le chemin à l'étude comporte une rainure en forme de V avec une largeur supérieure à X mm.

Règle: La *distance d'isolement* est la distance de "visibilité". Le chemin de la *ligne de fuite* suit le contour de la rainure, mais "court-circuite" la partie inférieure de la rainure par une liaison de X mm.

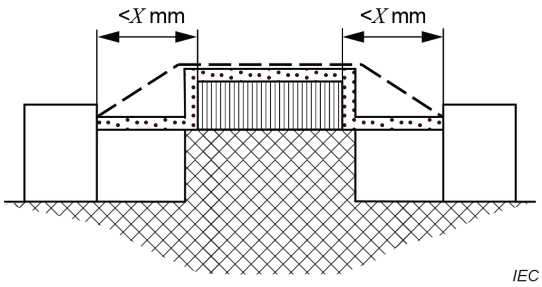
Figure D.3 – Exemple de mesurage incluant une rainure



Condition: Le chemin à l'étude comprend une nervure.

Règle: La *distance d'isolement* est la plus courte distance dans l'air au-dessus de la partie supérieure de la nervure. Le chemin de la *ligne de fuite* suit le contour de la nervure.

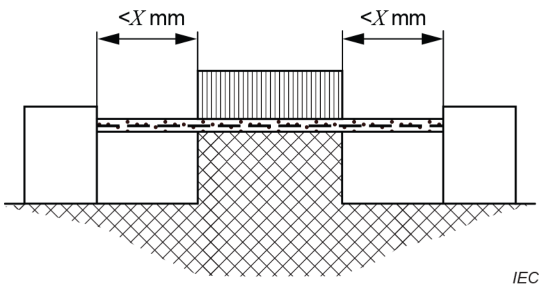
Figure D.4 – Exemple de mesurage incluant une nervure



Condition: Le chemin à l'étude comprend un joint scellé qui assure une protection de type 2 (voir 4.4.7.8.4.3) avec des rainures d'une largeur inférieure à X mm de chaque côté.

Règle: La *distance d'isolement* est la plus courte distance dans l'air au-dessus de la partie supérieure du raccord. La *ligne de fuite* est mesurée directement sur les rainures et suit le contour du raccord.

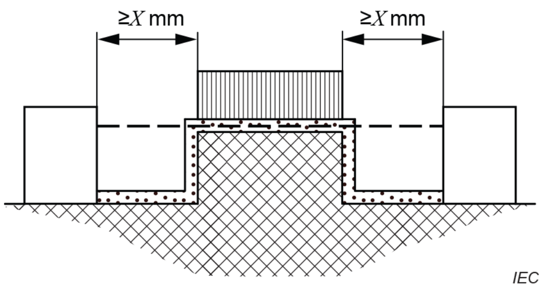
Figure D.5 – Exemple de mesurage assurant une protection de type 2



Condition: Le chemin à l'étude comprend un joint non scellé qui assure une protection de type 1 (voir 4.4.7.8.4.3) avec des rainures d'une largeur inférieure à X mm de chaque côté.

Règle: Le chemin de la *distance d'isolement* et de la *ligne de fuite* est la distance de "visibilité" indiquée.

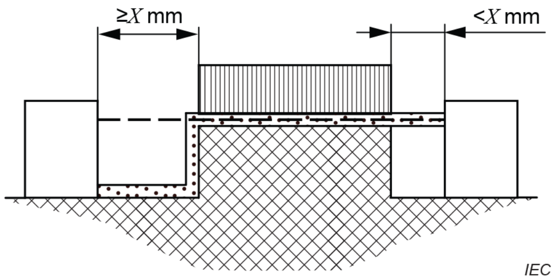
Figure D.6 – Exemple de mesurage assurant une protection de type 1



Condition: Le chemin à l'étude comprend un joint non scellé qui assure une protection de type 1 (voir 4.4.7.8.4.3) avec des rainures d'une largeur supérieure ou égale à X mm de chaque côté.

Règle: La *distance d'isolement* est la distance de "visibilité". Le chemin de la *ligne de fuite* suit le contour des rainures.

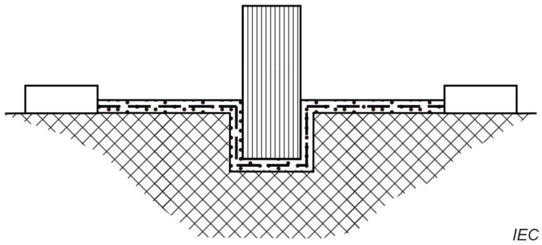
Figure D.7 – Exemple de mesurage assurant une protection de type 1



Condition: Le chemin à l'étude comprend un joint non scellé ou un joint scellé assurant une protection de type 1 (voir 4.4.7.8.4.3) avec une rainure sur un côté d'une largeur inférieure à X mm et la rainure sur l'autre côté d'une largeur supérieure ou égale à X mm.

Règle: Les chemins de la *distance d'isolement* et de la *ligne de fuite* sont tels que représentés.

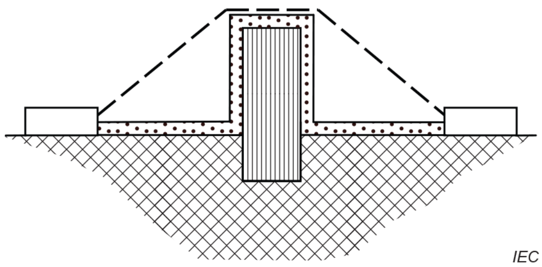
Figure D.8 – Exemple de mesurage assurant une protection de type 1



Condition: Le chemin à l'étude comporte une barrière non scellée ou un joint scellé qui assure une protection de type 1 (voir 4.4.7.8.4.3) lorsque le chemin sous la barrière est inférieur au chemin situé au-dessus de la barrière.

Règle: Les chemins de la *distance d'isolement* et de la *ligne* suivent le contour situé sous la barrière.

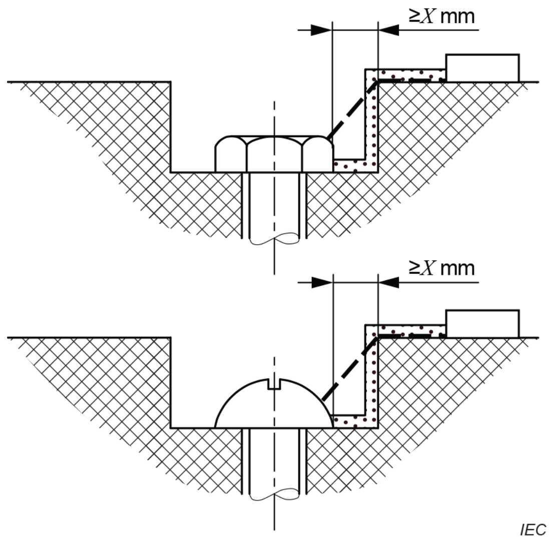
Figure D.9 – Exemple de mesurage incluant une barrière (joints scellés)



Condition: Le chemin considéré comprend une barrière non collée ou une barrière collée lorsque le chemin au-dessus de la barrière est plus court que le chemin situé en dessous de la barrière.

Règle: La *distance d'isolement* est la plus courte distance dans l'air au-dessus de la partie supérieure de la barrière. Le chemin de la *ligne de fuite* suit le contour de la barrière.

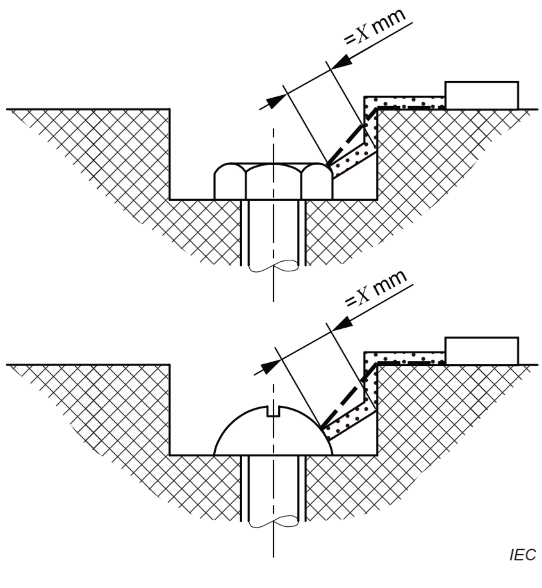
Figure D.10 – Exemple de mesurage incluant une barrière



Condition: Le chemin considéré comporte une ouverture entre la tête de la vis et la paroi du retrait d'une largeur supérieure ou égale à X mm.

Règle: La *distance d'isolement* est la plus courte distance dans l'air à travers l'ouverture et au-dessus de la surface supérieure. Le chemin de la *ligne de fuite* suit le contour des surfaces.

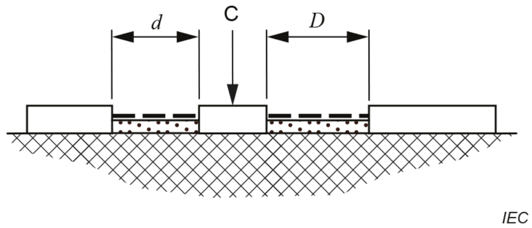
Figure D.11 – Exemple de mesurage incluant une ouverture



Condition: Le chemin à l'étude comporte une ouverture entre la tête de la vis et la paroi du retrait d'une largeur inférieure à X mm.

Règle: La *distance d'isolement* est la plus courte distance dans l'air à travers l'ouverture et au-dessus de la surface supérieure. Le chemin de la *ligne de fuite* suit le contour des surfaces mais "court-circuite" la partie inférieure du retrait par une liaison de X mm.

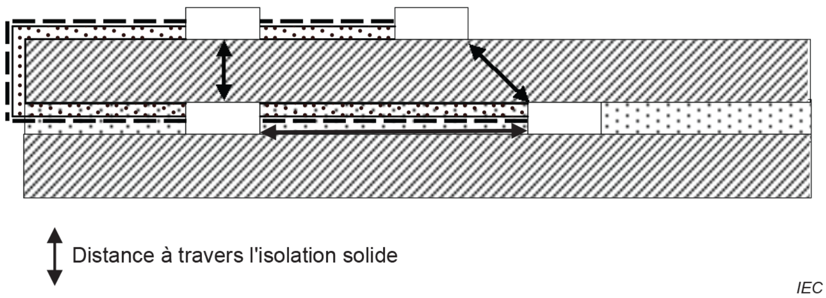
Figure D.12 – Exemple de mesurage incluant une ouverture



Condition: Le chemin considéré comporte une partie flottante d'un matériau conducteur C.

Règle: La somme de d plus D constitue les chemins de la *distance d'isolement* et de la *ligne de fuite*.

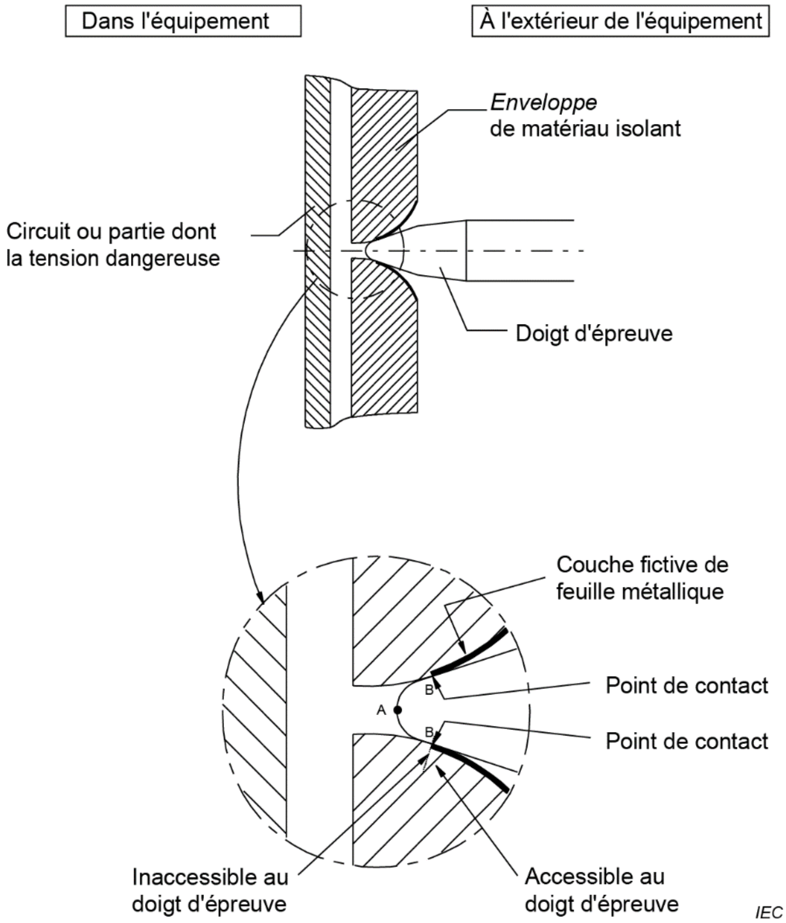
Figure D.13 – Exemple de mesurage incluant une partie conductrice flottante



Condition: Le chemin à l'étude inclut une couche interne de carte de circuit imprimé.

Règle: Concernant la ou les couches internes, la distance entre les pistes adjacentes d'une même couche est traitée en tant que *ligne de fuite* pour un degré de pollution 1 et en tant que *distance d'isolement* (voir 4.4.7.8.4.2 a)) ou qu'*isolation solide* (voir 4.4.7.8.4.2).

Figure D.14 – Exemple de mesurage dans une couche interne de carte de circuit imprimé



Le point A est utilisé pour déterminer l'entrefer vers la partie à l'intérieur de l'*enveloppe*.

Le point B est utilisé pour mesurer les *distances d'isolement* et les *lignes de fuite* entre l'extérieur d'une enveloppe de matériau isolant et une partie à l'intérieur de l'*enveloppe*.

Figure D.15 – Exemple de mesurage dans une enveloppe de matériau isolant

Annex E
(normative)

Correction d’altitude pour les *distances d’isolement*

E.1 Facteur de correction des *distances d'isolement* à des altitudes supérieures à 2 000 m

Dimensionnement des *distances d'isolement* entre 2 000 m et 20 000 m selon 4.4.7.4.3 en combinaison avec le facteur de correction du Tableau E.1.

Tableau E.1 – Facteur de correction pour les *distances d'isolement* à des altitudes comprises entre 2 000 m et 20 000 m

Altitude m	**Pression barométrique normale** kPa	**Facteur multiplicatif pour les *distances d'isolement***
2 000	80,0	1,00
3 000	70,0	1,14
4 000	62,0	1,29
5 000	54,0	1,48
6 000	47,0	1,70
7 000	41,0	1,95
8 000	35,5	2,25
9 000	30,5	2,62
10 000	26,5	3,02
15 000	12,0	6,67
20 000	5,5	14,50
Source: IEC 60664-1:2020, Tableau A.2. L'interpolation linéaire est autorisée. Voir l'IEC 60664-1:2020, 5.2.3.4.		

E.2 Tensions d'essai pour la vérification des *distances d'isolement* à différentes altitudes

Étant donné que la tension de tenue dépend de la pression atmosphérique et donc de la hauteur du laboratoire d'essai au-dessus du niveau de la mer, la tension d'essai (voir 5.2.3.2 et le Tableau 28) doit être corrigée selon le Tableau E.2.

Tableau E.2 – Tensions d'essai pour la vérification des *distances d'isolement* à différentes altitudes

Tension de tenue aux chocs en kV				
Altitude du laboratoire d'essai				
2 000 m [a]	**1 000 m**	**500 m**	**200 m**	**0 m**
0,33	0,36	0,37	0,38	0,39
0,50	0,54	0,56	0,57	0,58
0,80	0,87	0,90	0,92	0,93
1,50	1,6	1,7	1,7	1,8
2,50	2,8	2,9	3,0	3,1
4,00	4,4	4,7	4,8	4,9
6,00	6,7	7,0	7,2	7,4
8,00	8,9	9,4	9,6	9,8
12,00	13	14	15	15
20,00	22	24	24	25
40,00	45	47	49	50
60,00	67	71	73	75
75,00	84	89	92	94
80,00	90	95	98	100
95,00	106	112	116	119
100,00	112	118	122	125
125,00	140	148	153	157
145,00	163	172	178	182

NOTE 1 Des explications concernant les facteurs d'influence (air, pression, altitude, température, humidité) par rapport à la rigidité diélectrique des *distances d'isolement* sont données en 6.2.2.1.4 de l'IEC 60664-1:2020, 6.2.2.1.4.

NOTE 2 Lors des essais des *distances d'isolement*, l'*isolation solide* associée est soumise à la tension d'essai. Au fur et à mesure de l'augmentation de la *tension de tenue aux chocs* par rapport à la *tension de tenue aux chocs* assignée, l'*isolation solide* est ajustée en conséquence. Cela entraîne une augmentation de la capacité de tenue aux chocs de l'*isolation solide*.

NOTE 3 Les valeurs ci-dessus ont été arrondies par rapport celles calculées en 6.2.2.1.4 de l'IEC 60664-1:2020, 6.2.2.1.4.

[a] Valeurs du Tableau 6 et du Tableau 7.

Les valeurs de tension du Tableau E.2 s'appliquent pour la vérification des *distances d'isolement* uniquement.

Annex F
(normative)

Détermination de la *distance d'isolement* et de la *ligne de fuite* pour des fréquences supérieures à 30 kHz

F.1 Influence générale de la fréquence sur les caractéristiques de tenue

Les exigences d'*isolation* pour la *distance d'isolement*, la *ligne de fuite* et l'*isolation solide* mentionnées en 4.4.7 sont données pour des fréquences atteignant 30 kHz inclus. Pour les fréquences supérieures, il est nécessaire de prévoir et de prendre en compte une réduction de la capacité de tenue d'un type d'*isolation* pour le dimensionnement.

Pour les fréquences supérieures à 30 kHz et jusqu'à 10 MHz, l'IEC 60664-4:2005 doit être appliquée avec l'IEC 60664-1:2020 pour la conception de la *distance d'isolement*, de la *ligne de fuite* et de l'*isolation solide*.

L'Annex F donne des informations détaillées relatives à la conception de la *distance d'isolement*, de la *ligne de fuite* et de l'*isolation solide* en s'appuyant sur les exigences de l'IEC 60664-4:2005.

Il est nécessaire de prendre en considération la situation suivante dans le cadre de la conception:

- *distance d'isolement* pour les champs non homogènes (voir F.2.2);
- *distance d'isolement* pour les champs presque homogènes (voir F.2.3);
- *ligne de fuite* (voir l'Article F.3);
- *isolation solide* (voir l'Article F.4).

Le résultat de l'examen pour des fréquences supérieures à 30 kHz doit être comparé à l'examen du 4.4.7 et la valeur la plus élevée des deux examens doit être choisie.

F.2 Distance d'isolement

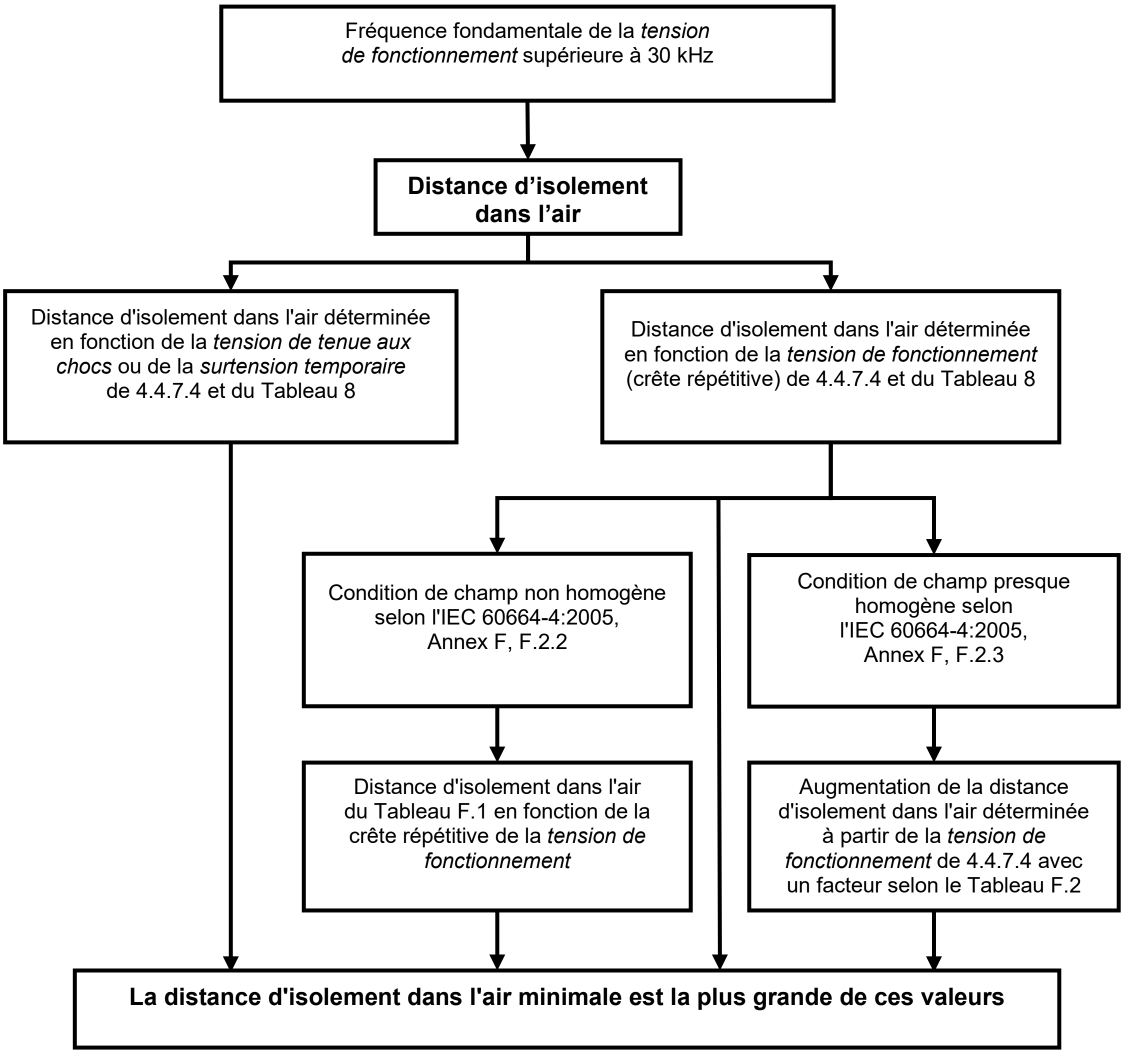
F.2.1 Généralités

T La capacité de tension de tenue dans le domaine d'application de l'IEC 60664-4:2005 est influencée par la fréquence pour des tensions périodiques. Pour les surtensions transitoires, le dimensionnement selon 4.4.7.4 doit être utilisé.

Pour les fréquences supérieures à 30 kHz dans les limites du domaine d'application de l'IEC 60664-4:2005, la capacité de tension de tenue des *distances d'isolement* avec une distribution de champs homogènes et presque homogènes peut être réduite de 25 % au maximum. Voir la Figure F.1.

Les exigences en matière de *distance d'isolement* dépendent de la distribution de champ de l'*isolation* à l'étude. Le paragraphe F.2.2 donne les exigences en matière de *distance d'isolement* pour les champs non homogènes, et le paragraphe F.2.3 donne les critères de conception des *distances d'isolement* pour des champs presque homogènes.

Pour les fréquences dépassant 30 kHz, un champ presque homogène est considéré comme existant lorsque le rayon de courbure r des parties conductrices est supérieur ou égal à 20 % de la *distance d'isolement*. Le rayon de courbure nécessaire ne peut être spécifié qu'à la fin de la procédure de dimensionnement.



Le résultat de l'examen de la *distance d'isolement* pour des fréquences supérieures à 30 kHz doit être comparé à l'examen du 4.4.7.4 et la valeur la plus élevée des deux examens doit être choisie.

Figure F.1 – Schéma de dimensionnement des *distances d'isolement* au-dessus de 30 kHz

F.2.2 *Distance d'isolement* pour des champs non homogènes

Pour les fréquences dépassant 30 kHz, un champ non homogène est considéré comme existant lorsque le rayon de courbure des parties conductrices est inférieur à 20 % de la *distance d'isolement*. Pour la distribution de champ non homogène, la réduction de la capacité de tension de tenue des *distances d'isolement* peut être bien plus élevée.

Le dimensionnement pour la distribution de champ non homogène est assuré pour la tension de tenue exigée de la *distance d'isolement* conformément aux valeurs du Tableau F.1. Aucun essai de tension de tenue autre que les exigences du 4.4.7 n'est exigé.

Tableau F.1 – Valeurs minimales des *distances d'isolement* à la pression atmosphérique dans des conditions de champ non homogènes

Tension de crête [a] kV	*Distance d'isolement* mm
≤ 0,6 [b]	0,065
0,8	0,18
1,0	0,5
1,2	1,4
1,4	2,35
1,6	4,0
1,8	6,7
2,0	11,0

SOURCE: IEC 60664-4:2005, Tableau 1.

[a] Pour les tensions intermédiaires de ce tableau, l'interpolation est permise.

[b] Aucune donnée n'est disponible pour les valeurs de crête inférieures à 0,6 kV.

Le dimensionnement pour des champs non homogènes et une contrainte de tension élevée (condition >1 kV) donnent des dimensions peu pratiques. Il est donc préférable de choisir une conception qui améliore la distribution du champ (distribution de champ presque homogène).

F.2.3 *Distance d'isolement* pour des champs presque homogènes

Pour les *distances d'isolement* dans des conditions de champs presque homogènes, la *distance d'isolement* du Tableau 8, déterminée en fonction de la *tension de fonctionnement* (crête répétitive) (colonne 3), est augmentée selon un facteur multiplicatif qui dépend de la fréquence fondamentale. Les facteurs multiplicatifs sont indiqués dans le Tableau F.2.

Tableau F.2 – Facteurs multiplicatifs pour les *distances d'isolement* à la pression atmosphérique pour des conditions de champs presque homogènes

Fréquence fondamentale kHz	Facteur multiplicatif
$30 < f_{\text{fondamentale}} \leq 500$	1,05
$500 < f_{\text{fondamentale}} \leq 1\,000$	1,10
$1\,000 < f_{\text{fondamentale}} \leq 2\,000$	1,20
$2\,000 < f_{\text{fondamentale}} \leq 3\,000$	1,25

NOTE 1 Les facteurs multiplicatifs sont déterminés sur la base des calculs selon l'IEC 60664-4:2005, 4.3.3. Un calcul plus précis peut être déterminé à l'aide de la formule de l'IEC 60664-4:2005, 4.3.3.

NOTE 2 Les circuits dans lesquels la *distance d'isolement* repose sur la *tension de tenue aux chocs* (Tableau 8, colonne 1) ne sont en principe pas affectés par ces considérations.

La *distance d'isolement* dimensionnée, dans les conditions de champs presque homogènes, s'applique aux fréquences supérieures à la fréquence critique calculée par la formule suivante en tenant compte de la nouvelle distance du Tableau F.2:

$$f_{\text{crit}} \approx \frac{0{,}2}{d}\left(\frac{\text{MHz}}{\text{mm}}\right)$$

F.3 *Lignes de fuite*

Pour les fréquences de la tension supérieures à 30 kHz, outre le suivi, il est nécessaire de tenir compte des effets thermiques par rapport à la capacité de tenue des *lignes de fuite*. Le dimensionnement est réalisé pour la tension de tenue en valeur efficace exigée de la *ligne de fuite* conformément aux valeurs du Tableau 10 et pour la tension de tenue crête exigée conformément aux valeurs du Tableau F.3. Cette tension de tenue crête est la valeur la plus élevée d'une crête périodique de la tension sur la *ligne de fuite*. La plus grande des distances s'applique. Le dimensionnement selon le Tableau F.3 s'applique à tous les matériaux isolants que les effets thermiques peuvent détériorer. Cela inclut les matériaux de base classiques pour cartes de circuit imprimé en résine d'époxy. Pour les matériaux que les effets thermiques ne peuvent pas détériorer et si aucun suivi n'est nécessaire, le dimensionnement en fonction des exigences de *distance d'isolement* comme cela est décrit en 4.4.7.5 est suffisant. Voir la Figure F.2.

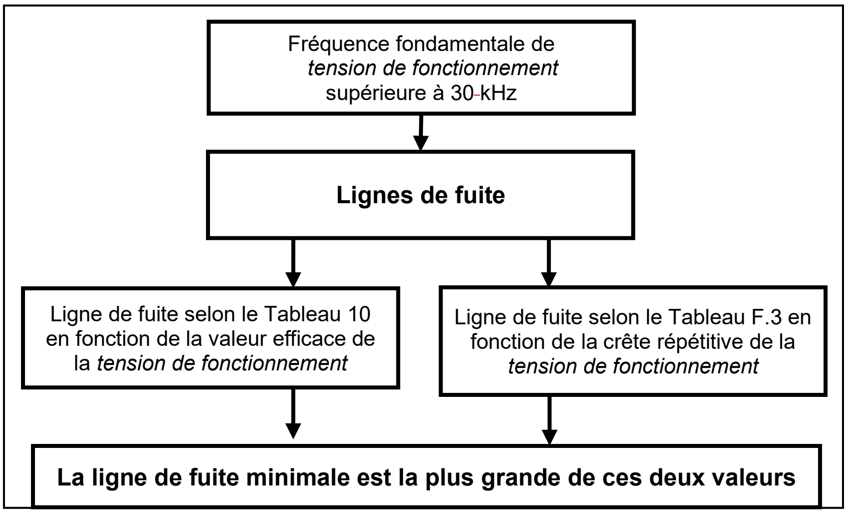


Figure F.2 – Schéma de dimensionnement des *lignes de fuite* au-dessus de 30 kHz

Tableau F.3 – Valeurs minimales des *lignes de fuite* pour différentes plages de fréquences

Tension de crête kV	*Ligne de fuite* [a] [b] mm						
	30 kHz < f ≤ 100 kHz	**f ≤ 0,2 MHz**	**f ≤ 0,4 MHz**	**f ≤ 0,7 MHz**	**f ≤ 1 MHz**	**f ≤ 2 MHz**	**f ≤ 3 MHz**
0,1	0,0167	--	--	--	--	--	0,3
0,2	0,042	--	--	--	--	0,15	2,8
0,3	0,083	0,09	0,09	0,09	0,09	0,8	20
0,4	0,125	0,13	0,15	0,19	0,35	4,5	--
0,5	0,183	0,19	0,25	0,4	1,5	20	--
0,6	0,267	0,27	0,4	0,85	5	--	--
0,7	0,358	0,38	0,68	1,9	20	--	--
0,8	0,45	0,55	1,1	3,8	--	--	--
0,9	0,525	0,82	1,9	8,7	--	--	--
1	0,6	1,15	3	18	--	--	--
1,1	0,683	1,7	5	--	--	--	--
1,2	0,85	2,4	8,2	--	--	--	--
1,3	1,2	3,5	--	--	--	--	--
1,4	1,65	5	--	--	--	--	--
1,5	2,3	7,3	--	--	--	--	--
1,6	3,15	--	--	--	--	--	--
1,7	4,4	--	--	--	--	--	--
1,8	6,1	--	--	--	--	--	--

SOURCE: IEC 60664-4:2005, Tableau 2.

[a] Les valeurs pour les *lignes de fuite* de ce tableau sont pour un degré de pollution 1. Un facteur multiplicatif de 1,2 doit être appliqué pour un degré de pollution 2 et un facteur multiplicatif de 1,4 doit être appliqué pour un degré de pollution 3.

[b] L'interpolation entre les colonnes est permise.

F.4 *Isolation solide*

F.4.1 Généralités

En raison de l'augmentation des effets thermiques et de la détérioration accélérée de l'*isolation solide*, une étude approfondie est nécessaire lorsque l'*isolation solide* est utilisée comme barrière d'*isolation* en présence de fréquences supérieures à 30 kHz.

F.4.2 Distribution de champs presque uniformes sans entrefer ni vide

Pour l'*isolation solide*, en présence d'une distribution de champ uniforme sans entrefer ni vide dans l'*isolation solide*, la distribution de champ maximale doit être calculée comme suit.

- Pour les couches épaisses d'*isolation solide* de $d1 \geq 0{,}75$ mm, il est nécessaire que la valeur de crête de l'intensité du champ E soit inférieure ou égale à 2 kV/mm.
- Pour les couches fines d'*isolation solide* de $d2 \leq 30$ µm, il est nécessaire que la valeur de crête de l'intensité du champ soit inférieure ou égale à 10 kV/mm.

Pour $d1 > d > d2$, la Formule (1) est utilisée pour l'interpolation correspondant à une certaine épaisseur d (voir également la Figure F.3)

$$E = \left(\frac{0{,}25}{d} + 1{,}667\right)\left(\frac{\text{kV}}{\text{mm}}\right) \tag{F.1}$$

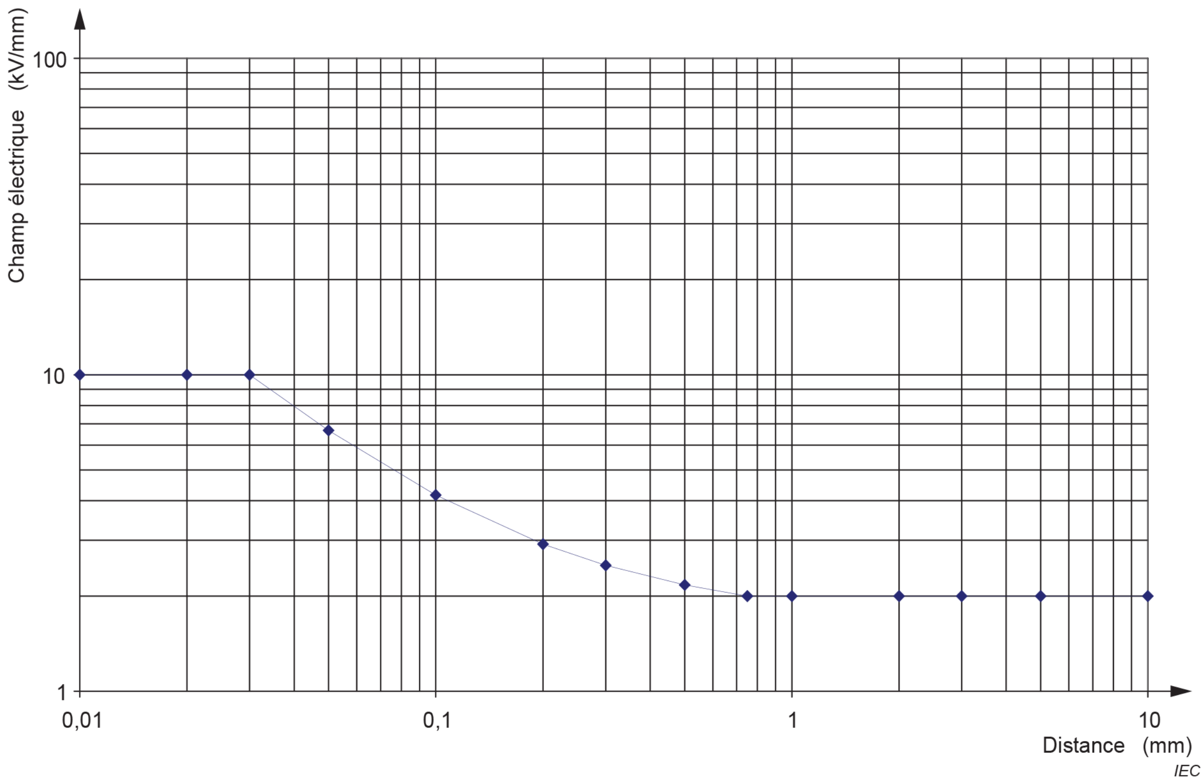


Figure F.3 – Intensité du champ admise pour le dimensionnement de l'*isolation solide* selon la Formule (F.1)

F.4.3 Autres cas

L'évaluation correspondante selon 4.4.7.8 pour l'*isolation solide* doit être réalisée lorsque

- il n'existe pas de distribution de champ uniforme,
- des entrefers ou des vides doivent être prévus, ou
- l'intensité du champ est supérieure à la valeur calculée en F.4.2.

Dans la mesure du possible, il convient de procéder à l'essai de décharge partielle décrit en 5.2.3.5 avec la fréquence, qui est présente sur l'*isolation* à l'étude lorsque l'évaluation est réalisée selon l'Annex F. Ce type d'équipement d'essai n'étant pas aisément disponible au moment de la rédaction, le présent document permet de procéder à l'essai à 50 Hz ou 60 Hz.

Annex G
(informative)

Sections des conducteurs ronds

Les valeurs normalisées de section des conducteurs en cuivre ronds sont indiquées dans le Tableau G.1, qui donne également la relation approximative entre les dimensions ISO métriques et les calibres AWG/MCM.

Tableau G.1 – Sections normalisées des conducteurs ronds

	AWG/kcmil	
Section ISO mm^2	**Dimension**	**Section équivalente** mm^2
0,2	24	0,205
–	22	0,324
0,5	20	0,519
0,75	18	0,82
1,0	–	–
1,5	16	1,3
2,5	14	2,1
4,0	12	3,3
6,0	10	5,3
10	8	8,4
16	6	13,3
25	4	21,2
35	2	33,6
50	0	53,5
70	00	67,4
95	000	85,0
–	0000	107,2
120	250 kcmil	127
150	300 kcmil	152
185	350 kcmil	177
240	500 kcmil	253
300	600 kcmil	304
–	700 kcmil	355
–	750 kcmil	380
400	800 kcmil	405
–	900 kcmil	456
500	1 000 kcmil	506
630	1 250 kcmil	633
–	1 500 kcmil	760
800	–	–
–	1 750 kcmil	887
1 000	2 000 kcmil	1 013
NOTE Le tiret, lorsqu'il est indiqué, vaut pour une dimension en ce qui concerne la capacité de raccordement (voir 4.11.11.2).		

Annex H
(informative)

Lignes directrices relatives à la compatibilité des DDR

H.1 Sélection du type de DDR

Selon la nature de l'alimentation, son *installation* et le type de DDR (type A, type AC, type B ou type F – voir l'IEC 60755), le *PDS* et le DDR peuvent être ou non compatibles (voir 4.4.8). Si les circuits pouvant provoquer un courant à composante continue dans le *conducteur de mise à la terre de protection* dans des conditions normales de fonctionnement ou en cas de *conditions de premier défaut* ne sont pas séparés de l'*environnement* par une *double insolation* ou une *isolation renforcée*, le *PDS* lui-même est considéré comme pouvant provoquer un courant continu filtré et de ce fait comme incompatible avec les DDR de type AC, de type A et de type F.

L'organigramme de la Figure H.1 facilite la sélection du type de DDR lorsqu'un *PDS* est utilisé en aval du DDR.

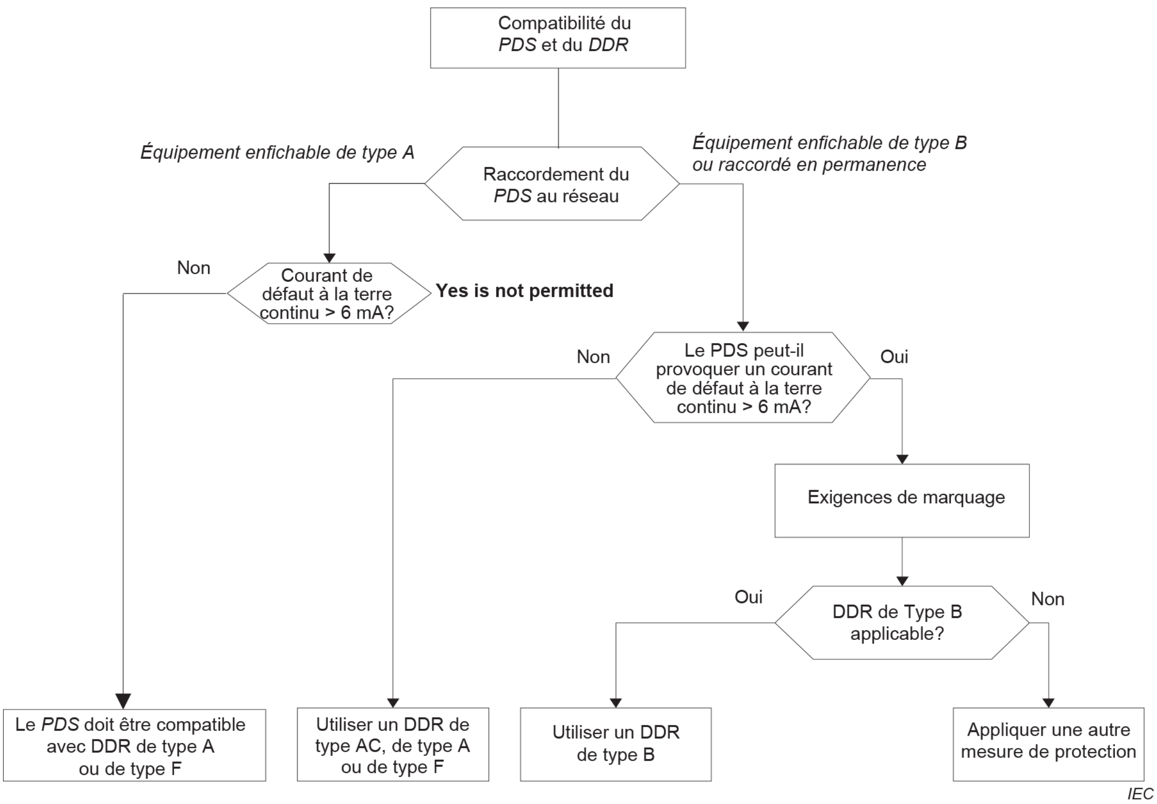


Figure H.1 – Organigramme conduisant à la sélection du type de DDR en amont d'un *PDS*

Les DDR aptes à être déclenchés par différentes formes d'ondes de courants résiduels sont marqués des symboles suivants de la Figure H.2, définis dans l'IEC 60755.

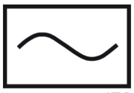
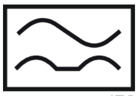
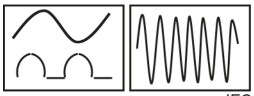
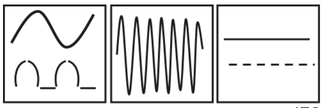
Symbole	Type de DDR et description
	Type AC (IEC 60417-6148:2012-01): – sensible au courant alternatif; – adapté pour la Figure H.3, circuit 1 et circuit 2.
	Type A (IEC 60417-6149:2012-01): – sensible au courant alternatif et sensible aux courants continus pulsatoires résiduels superposés à un courant continu filtré limité à 6 mA; – adapté pour la Figure H.3, circuits 1 à 5.
	Type F (IEC 60417-6149:2012-01 + IEC 60417-6160:2012-04): – sensible au courant alternatif et sensible aux courants continus pulsatoires résiduels superposés à un courant continu filtré limité à 10 mA; – adapté pour la Figure H.3, circuits 1 à 6.
	Type B (IEC 60417-6149:2012-01 + IEC 60417-6160:2012-04 + IEC 60417-6297:2014-11): – sensible au courant universel; – adapté pour la Figure H.3, tous les circuits.

Figure H.2 – Symboles pour le marquage en fonction du type de DDR

H.2 Formes d'ondes des courants de défaut

La Figure H.3 présente les formes d'ondes de courant de défaut à la terre des *systèmes* reliés à la terre au point neutre où une composante continue peut se produire, pour différentes configurations d'équipements électroniques de puissance et de *PDS* utilisées pour déterminer la compatibilité du DDR.

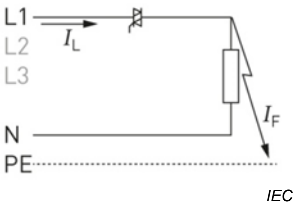
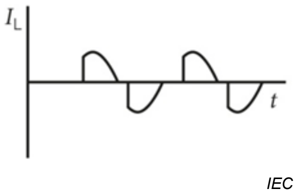
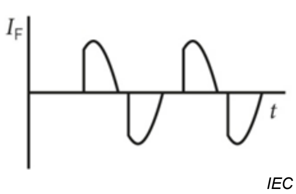
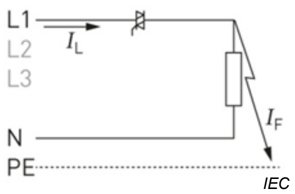
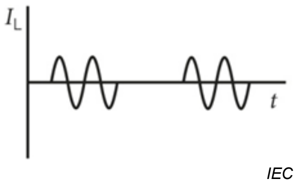
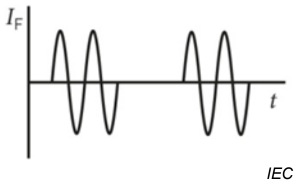
	Schéma des circuits avec emplacement de défaut	Forme du courant de charge I_L	Forme du courant de défaut à la terre I_F	Caractéristique de déclenchement du DDR
1	Réglage de phase 			**AC, A, F, B**
2	Commande par salves 			**AC, A, F, B**

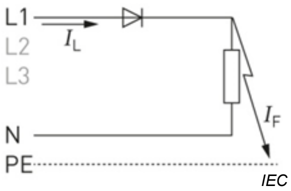
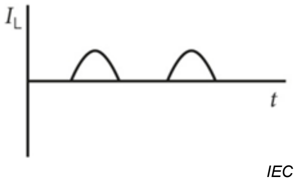
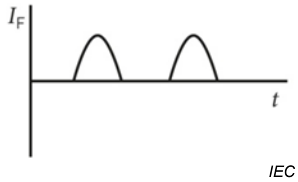
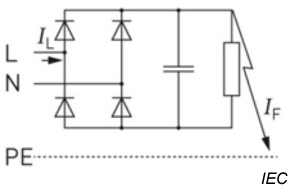
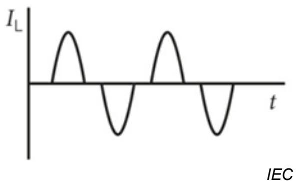
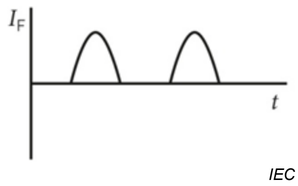
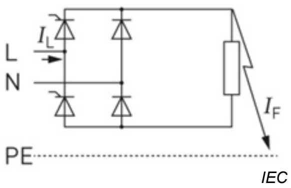
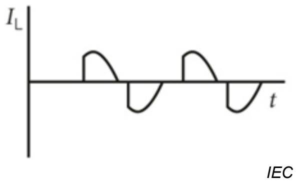
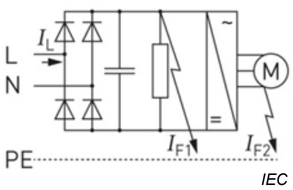
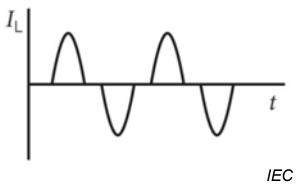
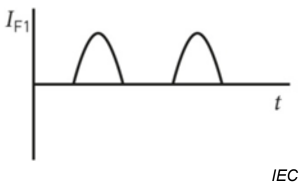
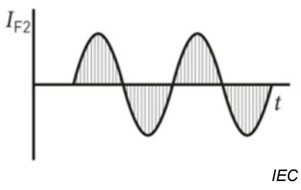
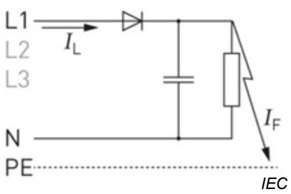
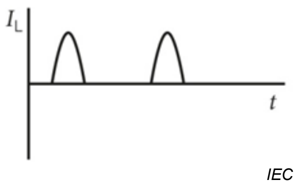
	Schéma des circuits avec emplacement de défaut	**Forme du courant de charge I_L**	**Forme du courant de défaut à la terre I_F**	**Caractéristique de déclenchement du DDR**
3	Monophasé 			**A, F, B**
4	Pont à double alternance 			**A, F, B**
5	Pont à double alternance, semicommandé 			**A, F, B**
6	Onduleur de fréquence avec pont à double alternance 		 	**F, B**
7	Monophasé avec lissage 			**B**

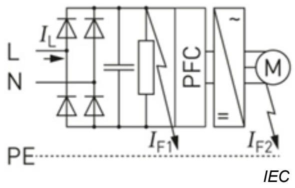
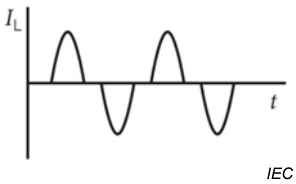
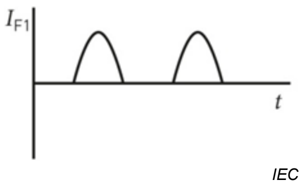
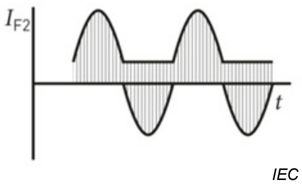
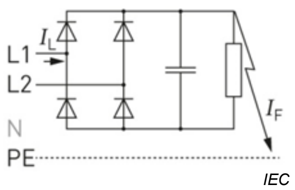
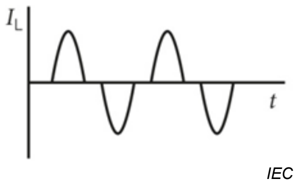
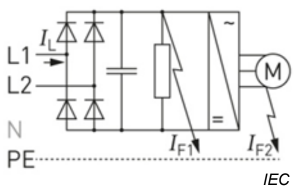
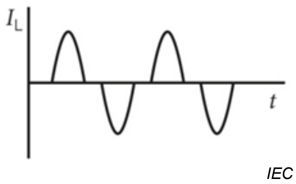
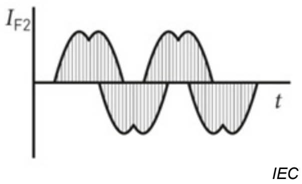
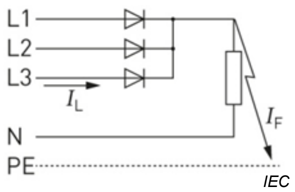
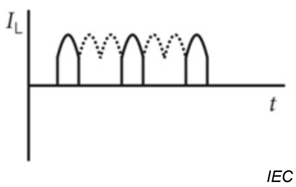
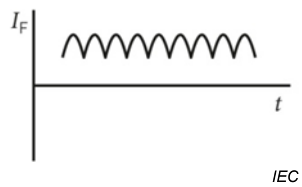
	Schéma des circuits avec emplacement de défaut	**Forme du courant de charge I_L**	**Forme du courant de défaut à la terre I_F**	**Caractéristique de déclenchement du DDR**
8	Onduleur de fréquence avec pont à double alternance et PFC (correction du facteur de puissance) 		 	**B**
9	Pont à double alternance, entre phases 			**B**
10	Onduleur de fréquence avec pont à double alternance entre phases 		 	**B**
11	Triphasé étoile 			**B**

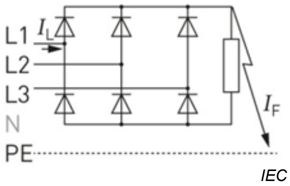
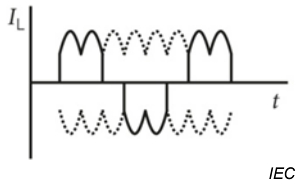
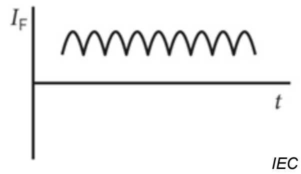
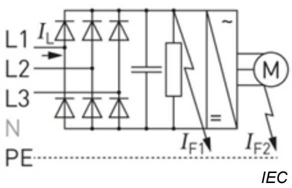
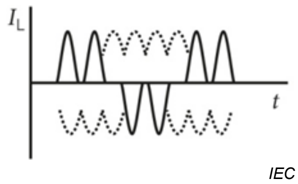
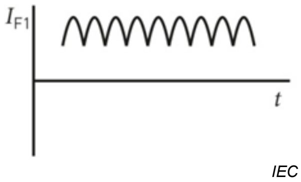
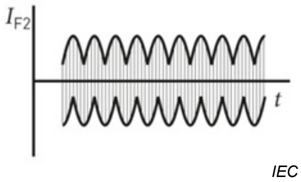
	Schéma des circuits avec emplacement de défaut	Forme du courant de charge I_L	Forme du courant de défaut à la terre I_F	Caractéristique de déclenchement du DDR
12	Pont à six alternances 			**B**
13	Onduleur de fréquence avec pont à six alternances 		 	**B**
Source: IEC 60755:2017, Annexe B. NOTE I_F symbolise un courant de défaut, pas un courant de court-circuit.				

Figure H.3 – Formes d’ondes des courants de défaut dans des montages avec *BDM/CDM/PDS*

Annex I
(informative)

Exemples de réductions de la catégorie de surtension

I.1 Généralités

Les figures de la Figure I.1 à la Figure I.13 présentent les exigences du Tableau 3, du Tableau 6, du 4.4.7.2 et du 4.4.7.3. Elles ne représentent pas des bonnes pratiques de conception recommandées.

- - - - - - - - -	protection pour empêcher les personnes de toucher les *parties actives dangereuses*, voir 4.4.3.3
▬ ▬ ▬ ▬ ▬	*parties accessibles* conductrices, voir 4.4.4.1
-·-·-·-·-·-	*protection renforcée, voir* 4.4.5.1
SPD	parafoudre (exemple de mesure pour réduire les surtensions transitoires)
OVC	catégorie de surtension

I.2 Protection par rapport à l'*environnement* (voir 4.4.7.2)

I.2.1 Circuits connectés directement au *réseau* (voir 4.4.7.2.3)

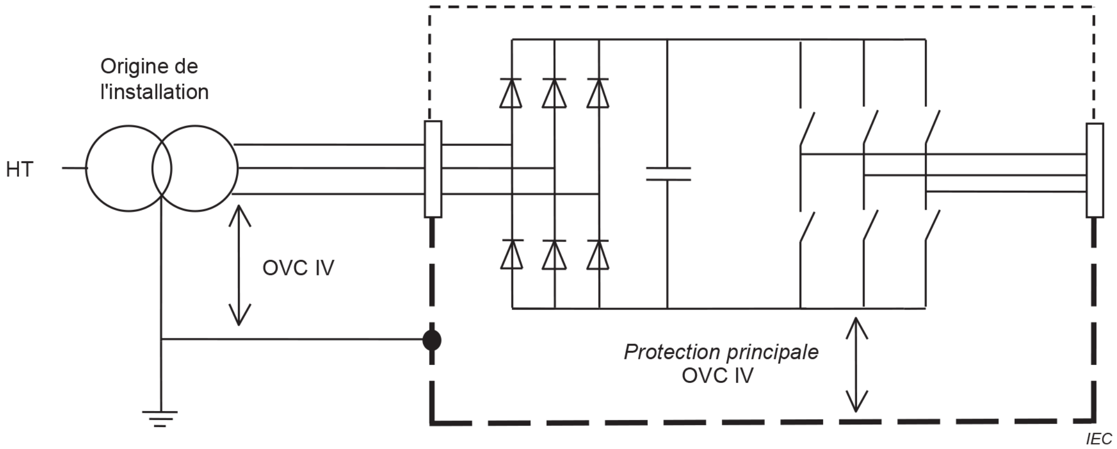


Figure I.1 – Évaluation de la *protection principale* pour les circuits connectés à l'origine du *réseau* de l'*installation*

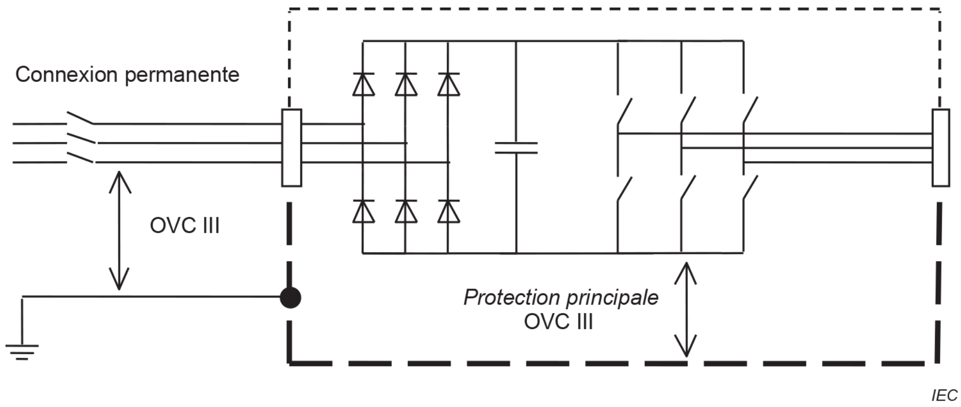


Figure I.2 – *Évaluation de la protection principale* pour les *circuits* connectés au *réseau*

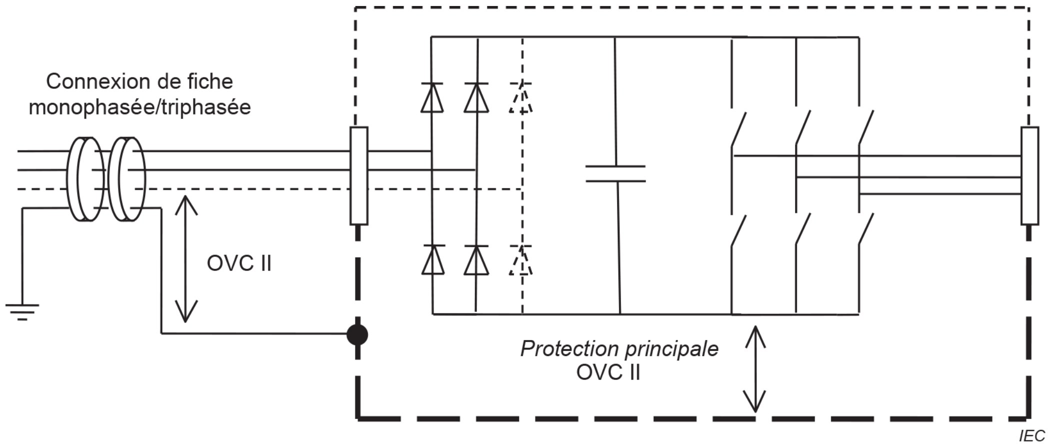


Figure I.3 – *Évaluation de la protection principale* pour les *BDM/CDM/PDS* monophasés et triphasés non *connectés en permanence* au *réseau*

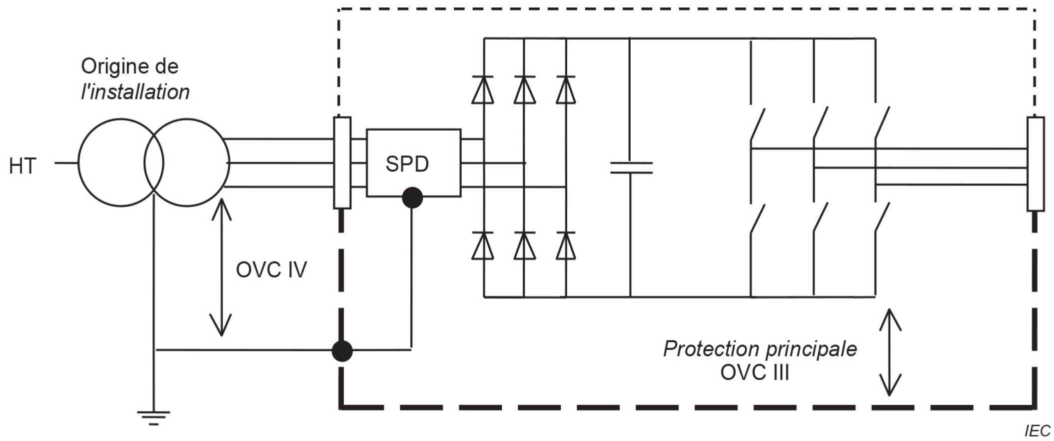


Figure I.4 – Évaluation de la *protection principale* pour les circuits connectés à l'origine du *réseau* de l'*installation* où des SPD internes sont utilisés

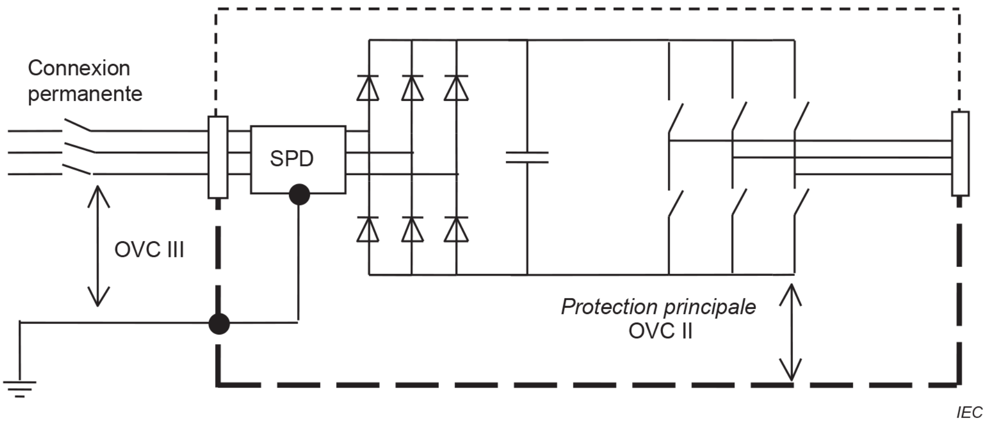


Figure I.5 – Évaluation de la *protection principale* pour les circuits connectés au *réseau* où des SPD internes sont utilisés

NOTE Pour les exigences relatives à la *protection principale* réduite en aval du *SPD*, voir 4.4.7.2.3 ou 4.4.7.2.4.

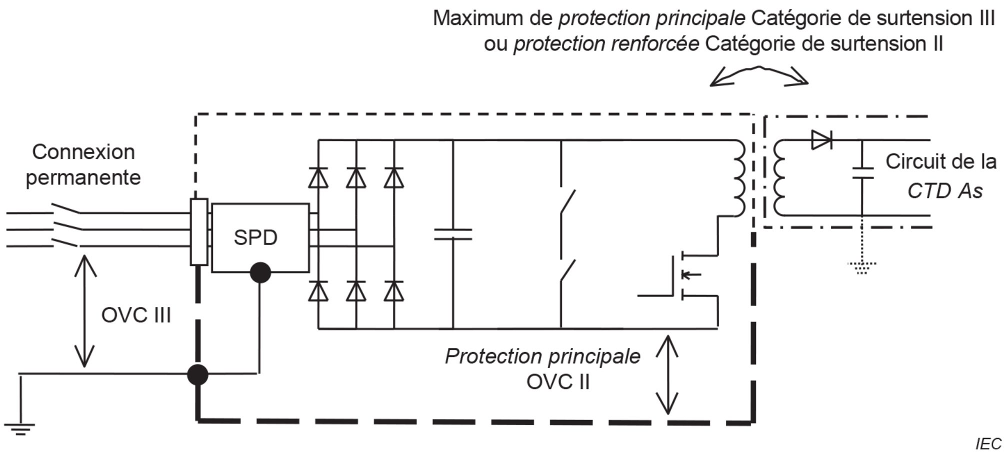


Figure I.6 – Exemple d'évaluation de la *protection renforcée* pour les circuits connectés au réseau où des SPD internes sont utilisés

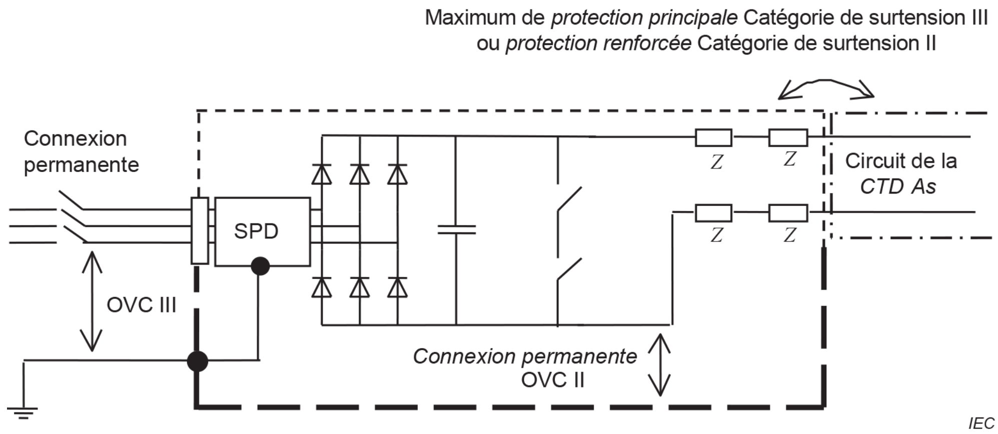


Figure I.7 – Exemple d'évaluation de la *protection renforcée* pour les circuits connectés au *réseau* où des SPD internes sont utilisés

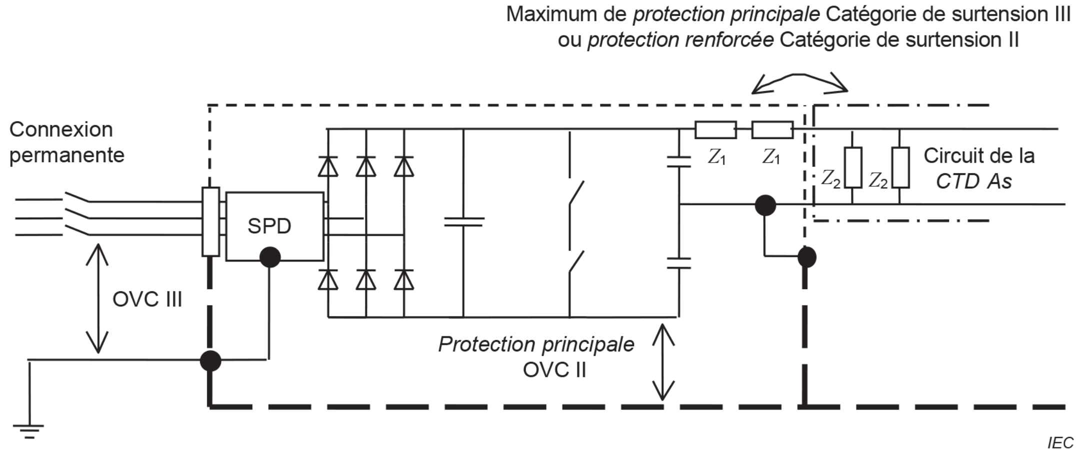


Figure I.8 – Exemple d'évaluation de la protection renforcée pour les circuits connectés au *réseau* où des SPD internes sont utilisés

NOTE Les exigences de la *protection renforcée* de la Figure I.6 à la Figure I.8 ne sont pas réduites par l'utilisation du *SPD* (voir 4.4.7.2.3 et 4.4.7.2.4).

I.2.2 Circuits connectés à l'*alimentation non raccordée directement au réseau* (voir 4.4.7.2.4)

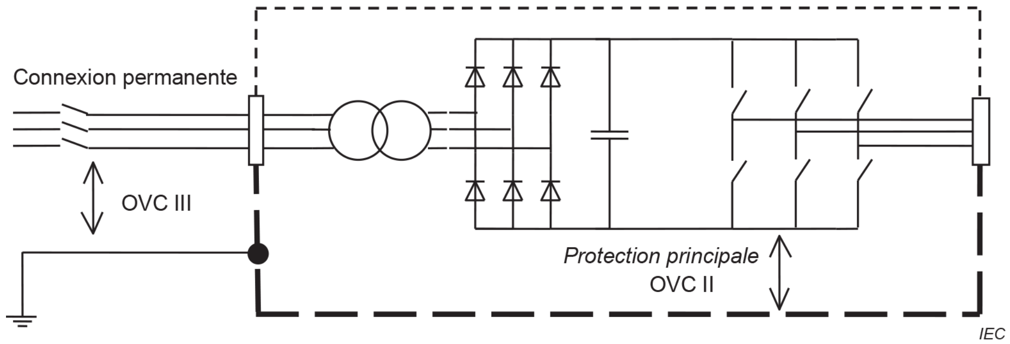


Figure I.9 – *Évaluation de la protection principale* pour les circuits connectés à l'*alimentation non raccordée directement au réseau*

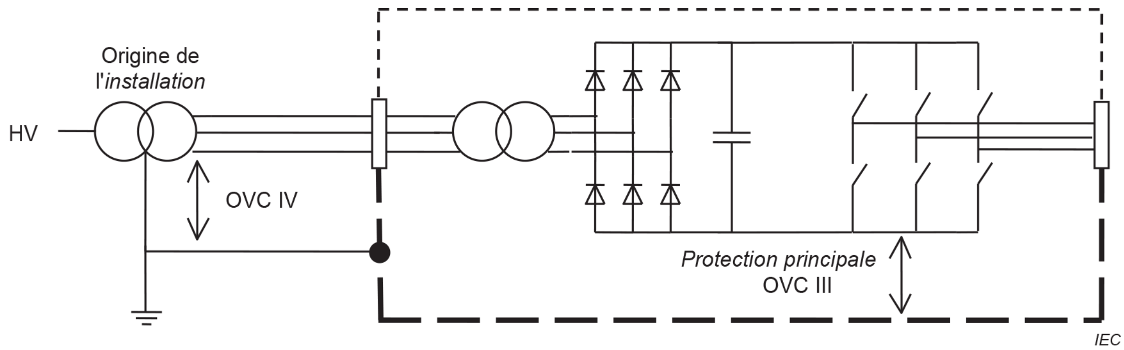
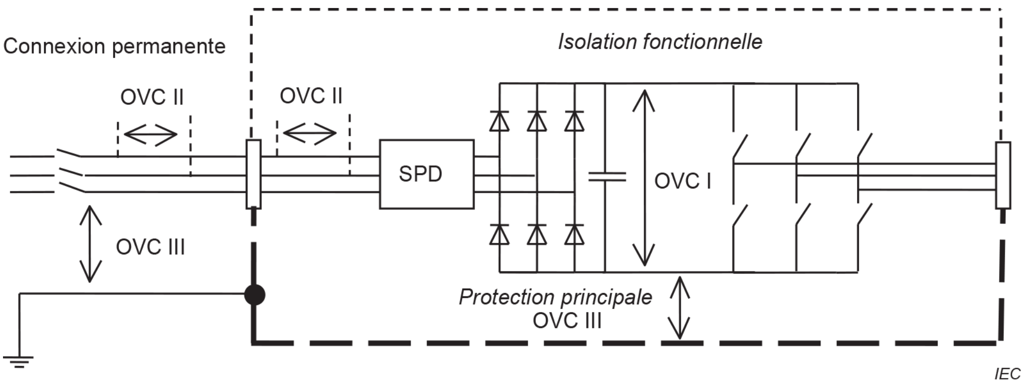


Figure I.10 – Évaluation de la *protection principale* pour les circuits connectés à l'origine de l'*alimentation non raccordée directement à l'installation*

I.2.3 *Isolation* entre les circuits (voir 4.4.7.2.5)

L'*isolation* entre deux circuits doit être conçue en fonction du circuit ayant les exigences les plus strictes (voir également la Figure I.12).

I.3 *Isolation fonctionnelle* (voir 4.4.7.3)



NOTE 1 Le *SPD* n'est pas connecté à la terre et n'a donc pas d'effet sur la catégorie de surtension à la terre.

NOTE 2 Les exigences d'une *isolation fonctionnelle* peuvent être encore réduites par les caractéristiques du circuit (voir 4.4.7.3).

Figure I.11 – Évaluation de l'*isolation fonctionnelle* dans les circuits affectés par des transitoires externes

I.4 Autres exemples

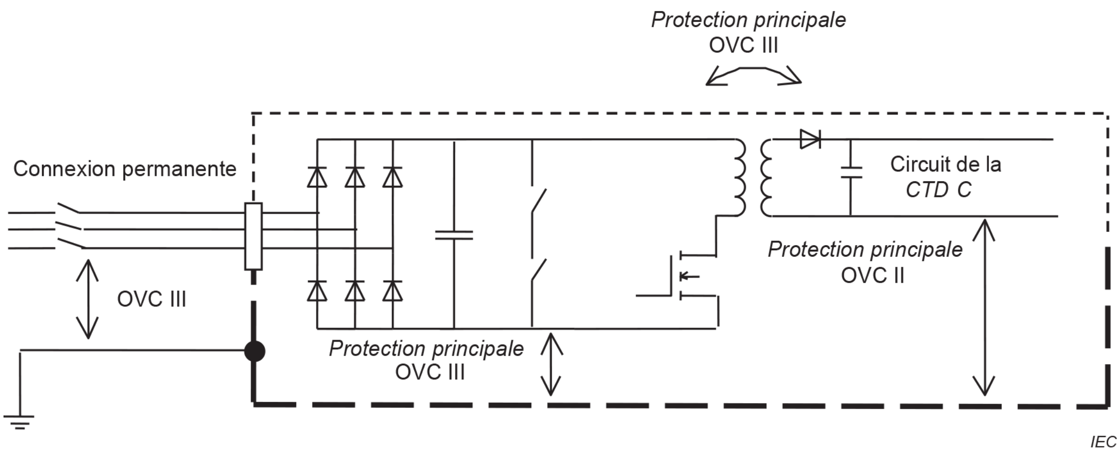


Figure I.12 – Évaluation de la *protection principale* pour les circuits connectés au *réseau* et pour un circuit *non raccordé directement au réseau*

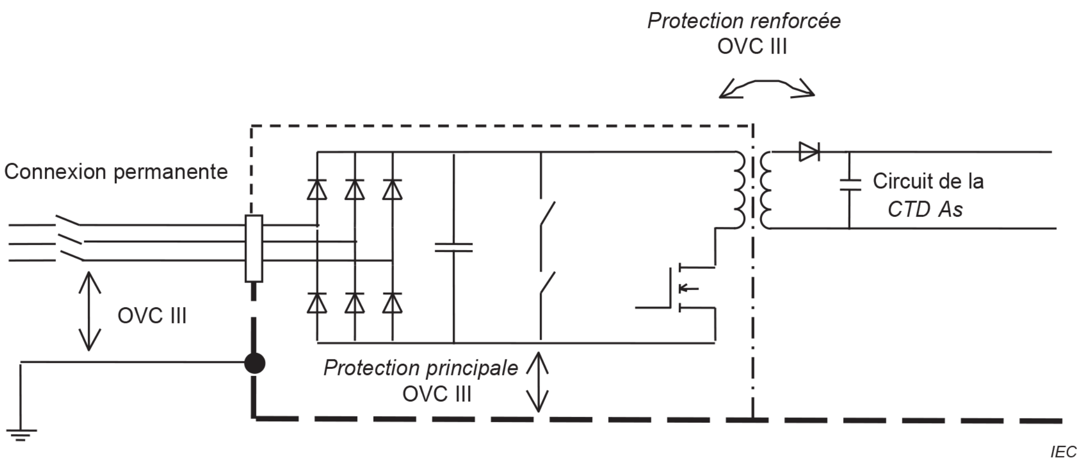


Figure I.13 – Évaluation de l'*isolation* pour les circuits accessibles de la *CTD* As

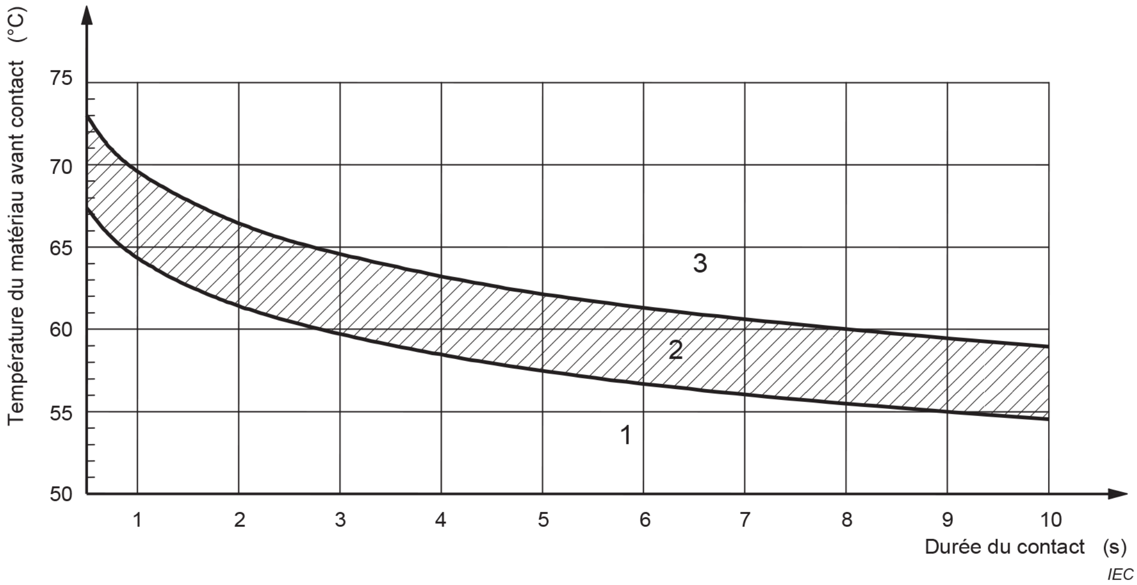
Annex J
(informative)

Seuils de brûlure pour les surfaces qui peuvent être touchées

J.1 Généralités

L'Annex J contient des informations relatives aux seuils de brûlure des surfaces qui peuvent être touchées pour différents matériaux. La Figure J.1, la Figure J.2, la Figure J.3, la Figure J.4 et la Figure J.5 sont des copies des figures du Guide IEC 117:2010.

J.2 Seuils de brûlure



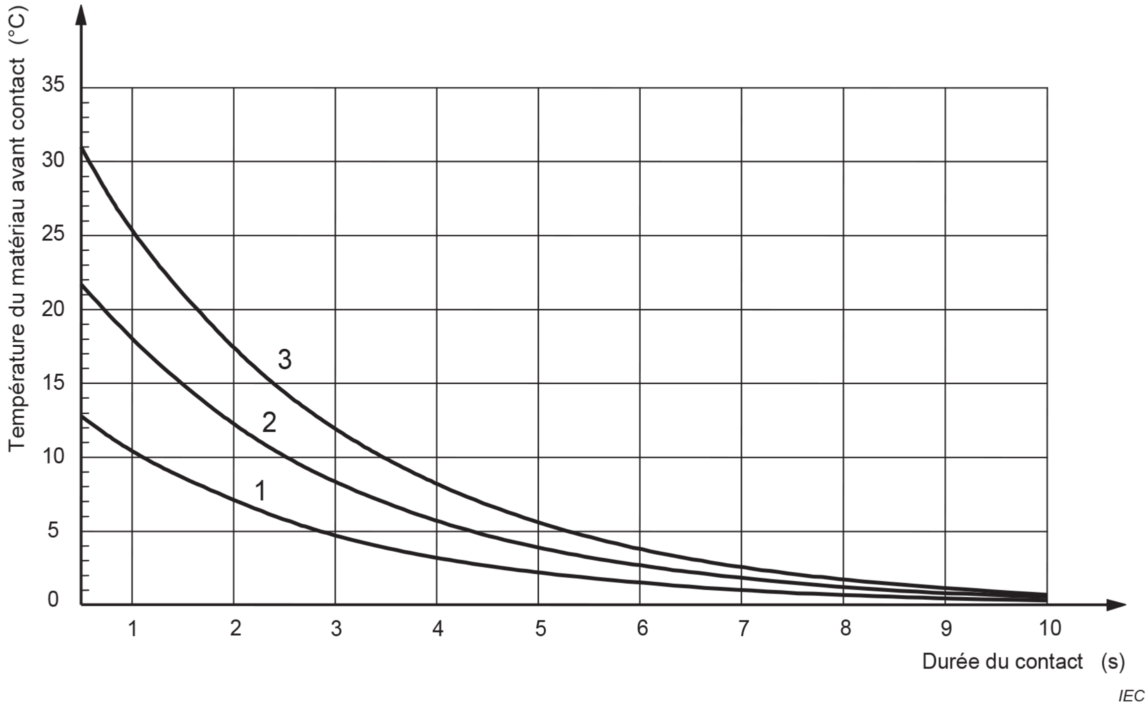
Légende

1 pas de brûlure

2 seuil de brûlure

3 brûlure

Figure J.1 – Seuil de brûlure diffusé lorsque la peau est en contact avec une surface lisse brûlante en métal nu (non revêtu)



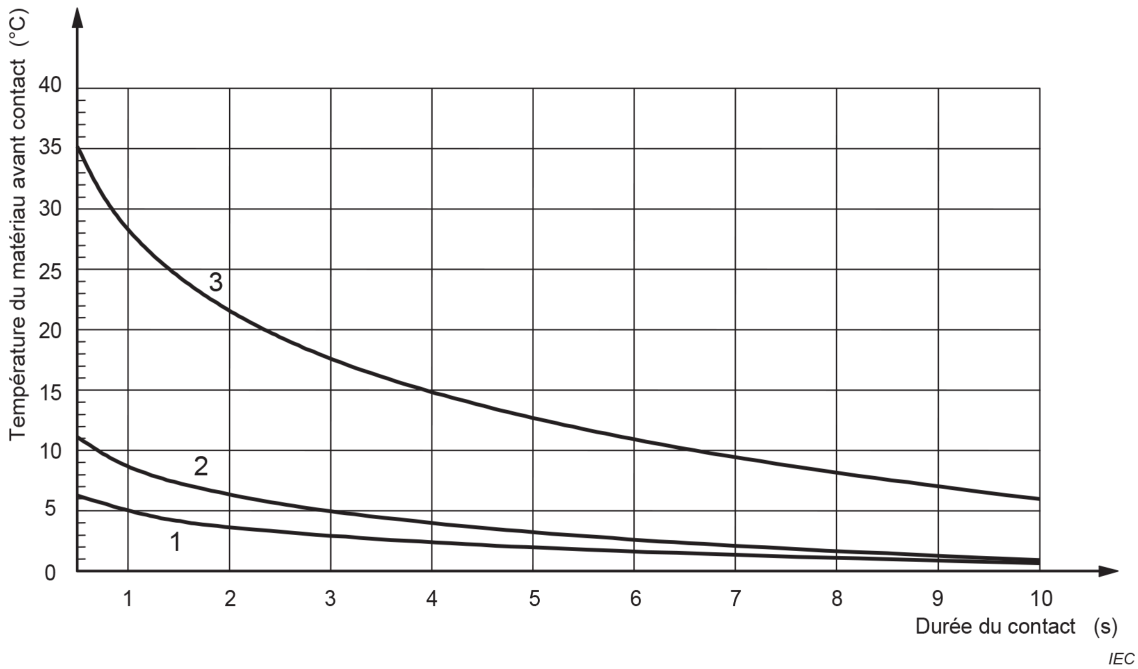
Légende

1 revêtu d'une gomme-laque d'une épaisseur de 50 µm

2 revêtu d'une gomme-laque d'une épaisseur de 100 µm

3 revêtu d'une gomme-laque d'une épaisseur de 150 µm

Figure J.2 – Hausse du seuil de brûlure diffusé de la Figure J.1 pour les métaux revêtus d'une gomme-laque d'une épaisseur de 50 µm, 100 µm et 150 µm



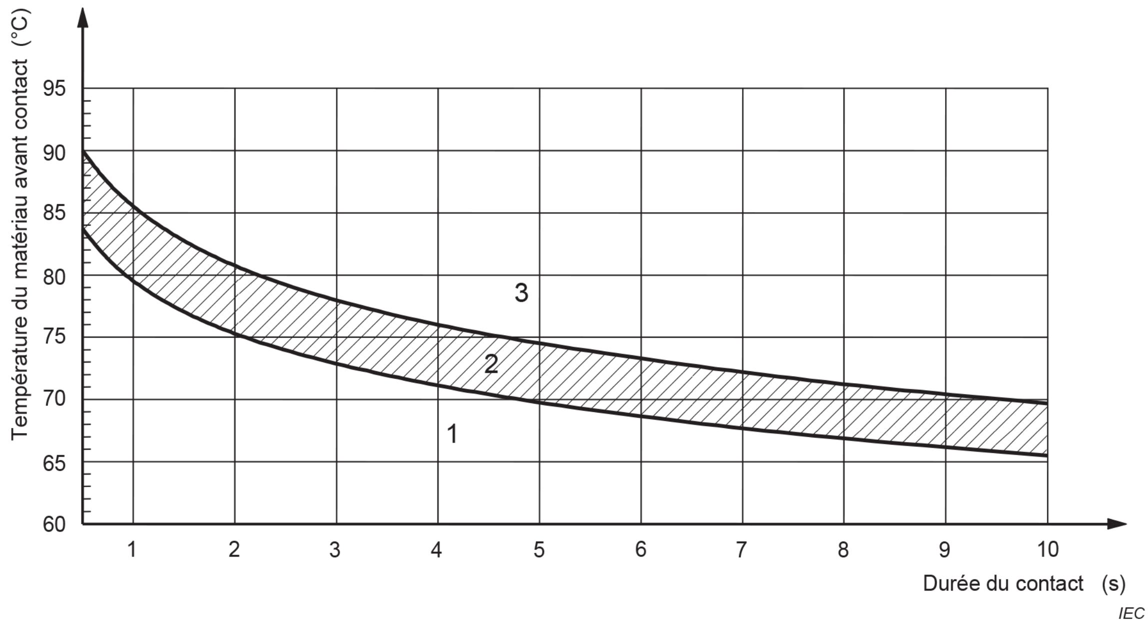
Légende

1 émail vitrifié (épaisseur de 160 µm)/surface peinte avec de la poudre (épaisseur de 60 µm)

2 surface peinte avec de la poudre (épaisseur de 90 µm)

3 polyamide 11 ou 12 (épaisseur de 400 µm)

Figure J.3 – Hausse du seuil de brûlure diffusé de la Figure J.1 pour les métaux revêtus de matériaux spécifiques



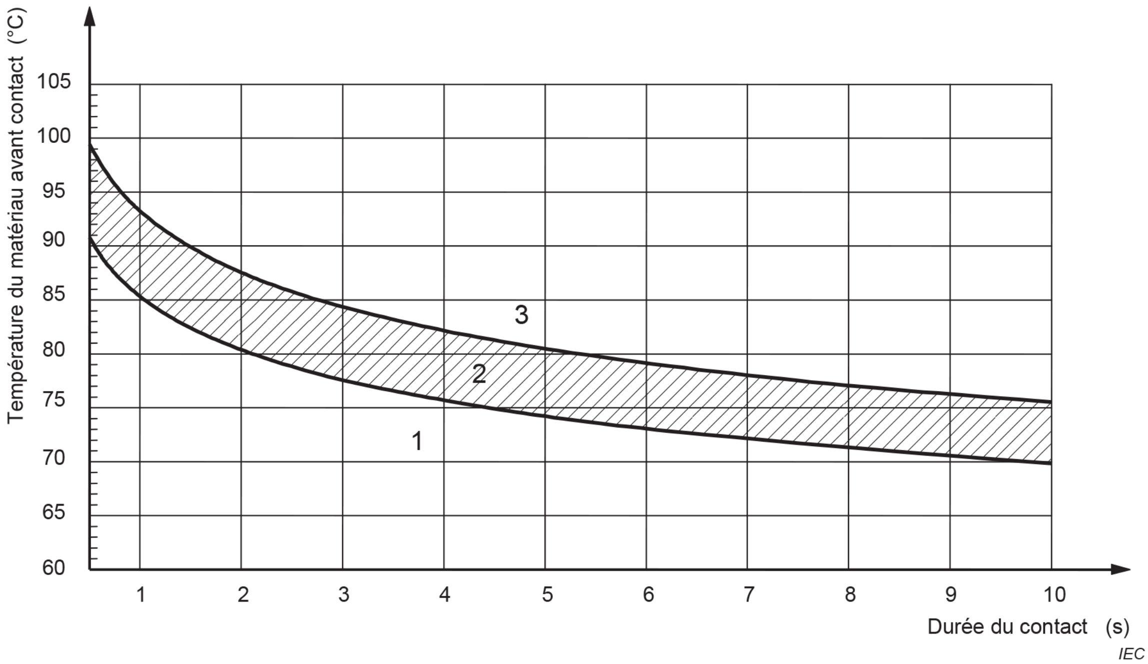
Légende

1 pas de brûlure

2 seuil de brûlure

3 brûlure

Figure J.4 – Seuil de brûlure diffusé lorsque la peau est en contact avec une surface lisse brûlante en céramique, en verre et en pierre



Légende

1 pas de brûlure

2 seuil de brûlure

3 brûlure

Figure J.5 – Seuil de brûlure diffusé lorsque la peau est en contact avec une surface lisse brûlante en plastique

Annex K
(informative)

Tableau des potentiels électrochimiques

Le Tableau K.1 présente les potentiels électrochimiques. La corrosion due à l'action électrochimique entre des métaux dissemblables qui sont en contact est réduite le plus possible si le potentiel électrochimique combiné est inférieur à environ 0,6 V. Dans le Tableau K.1, les potentiels électrochimiques combinés sont répertoriés pour un certain nombre de paires de métaux couramment utilisées. Il convient d'éviter les combinaisons au-dessus de la ligne de séparation.

Tableau K.1 – Tableau des potentiels électrochimiques

Magnésium, alliages de magnésium	Zinc, alliages de zinc	80 étain/20 Zn sur acier, ZN sur fer ou acier	Aluminium	Cd sur acier	Alliage Al/Mg	Acier doux	Duralumin	Plomb	Cr sur acier, brasure tendre	CR sur Ni sur acier, étain sur acier 12% acier	Acier inoxydable Cr élevé	Cuivre, alliages de cuivre	Brasure à l'argent, acier inoxydable austénitique	Ni sur acier	Argent	Rh sur Ag sur Cu, alliage argent/or	Carbone	Or, platine	
0	0,5	0,55	0,7	0,8	0,85	0,9	1,0	1,05	1,1	1,15	1,25	1,35	1,4	1,45	1,6	1,65	1,7	1,75	Magnésium, alliages de magnésium
--	0	0,05	0,2	0,3	0,35	0,4	0,5	0,55	0,6	0,65	0,75	0,85	0,9	0,95	1,1	1,15	1,2	1,25	Zinc, alliages de zinc
--	--	0	0,15	0,25	0,3	0,35	0,45	0,5	0,5	0,6	0,7	0,8	0,85	0,9	1,05	1,1	1,15	1,2	80 étain/20 Zn sur acier, ZN sur fer ou acier
--	--	--	0	0,1	0,15	0,2	0,3	0,35	0,4	0,45	0,55	0,65	0,7	0,75	0,9	0,95	1,0	1,05	Aluminium
--	--	--	--	0	0,05	0,1	0,2	0,25	0,3	0,35	0,45	0,55	0,6	0,65	0,8	0,85	0,9	0,95	Cd sur acier
--	--	--	--	--	0	0,05	0,15	0,2	0,2	0,3	0,4	0,5	0,55	0,6	0,75	0,8	0,85	0,9	Alliage Al/Mg
--	--	--	--	--	--	0	0,1	0,15	0,2	0,25	0,35	0,45	0,5	0,55	0,7	0,75	0,8	0,85	Acier doux
--	--	--	--	--	--	--	0	0,05	0,1	0,15	0,25	0,35	0,4	0,45	0,6	0,65	0,7	0,75	Duralumin
--	--	--	--	--	--	--	--	0	0,5	0,1	0,2	0,3	0,35	0,4	0,55	0,6	0,66	0,7	Plomb
--	--	--	--	--	--	--	--	--	0	0,05	0,15	0,25	0,3	0,35	0,5	0,55	0,6	0,65	Cr sur acier, brasure tendre
--	--	--	--	--	--	--	--	--	--	0	0,1	0,2	0,25	0,3	0,45	0,5	0,55	0,6	CR sur Ni sur acier, étain sur acier 12% acier inoxydable Cr
--							--	--	--	--	0	0,1	0,15	0,2	0,35	0,4	0,45	0,5	Acier inoxydable Cr élevé
--							--	--	--	--		0	0,05	0,1	0,25	0,3	0,35	0,4	Cuivre, alliages de cuivre
--							--	--	--	--	--	--	0	0,05	0,2	0,25	0,3	0,35	Brasure à l'argent, acier inoxydable austénitique
--							--	--	--	--	--	--	--	0	0,15	0,2	0,25	0,3	Ni sur acier
--							--	--	--	--	--	--	--	--	0	0,05	0,1	0,15	Argent
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	0,05	0,1	Rh sur Ag sur Cu, alliage argent/or
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	0,05	Carbone
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	Or, platine

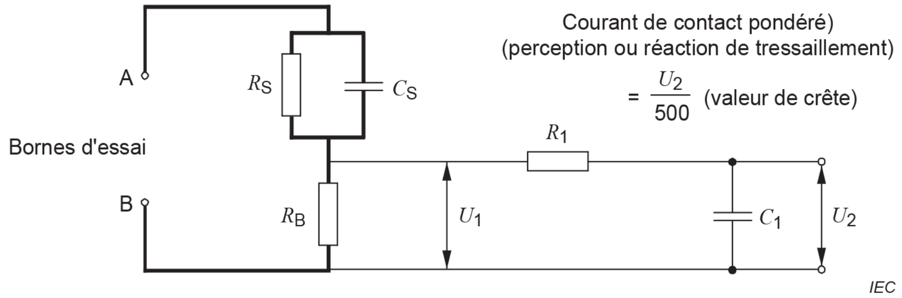
Ag	Argent
Al	Aluminium
Cd	Cadmium
Cr	Chrome
Cu	Cuivre
Mg	Magnésium
Ni	Nickel
Rh	Rhodium
Zn	Zinc

Annex L
(informative)

Instrument de mesure du courant de contact

L.1 Circuit d'essai de mesure

Le circuit d'essai de mesure de la Figure L.1 est issu de l'IEC 60990:2016, Figure 4.



Légende

R_S	1 500 Ω	R_1	10 kΩ
R_B	500 Ω	C_1	0,022 µF
C_S	0,22 µF		

Figure L.1 – Circuit d'essai de mesure

L.2 Exigences relatives aux instruments de mesure

La bande passante des instruments de mesure électrique doit permettre de fournir des relevés exacts, en tenant compte de toutes les composantes de fréquence (fréquence de *réseau* en courant continu et en courant alternatif, haute fréquence et résidu harmonique) du paramètre mesuré. Si la valeur efficace est mesurée, il faut veiller à ce que les instruments de mesure donnent des relevés vrais en valeur efficace des formes d'ondes non sinusoïdales et des formes d'ondes sinusoïdales.

Résistance d’entrée du voltmètre ou de l'oscilloscope (relevé en valeur efficace ou en valeur de crête): > 1 MΩ .

Capacité d'entrée: < 200 pF.

Plage de fréquences: 15 Hz jusqu'à 1 MHz (appropriée à la fréquence la plus élevée à l'étude).

Annex M
(normative)

Doigts d'épreuve pour la détermination de l'accès

Les figures de la Figure M.1 à la Figure M.4 sont reproduites à partir de l'IEC 61032:1997 pour des raisons pratiques uniquement.

Ces doigts d'essai sont utilisés pour l'essai de non-accessibilité (*essai de type*) du 5.2.2.2 et l'essai de force constante du 5.2.2.4.2.2.

Toutes les dimensions des figures ci-dessous sont exprimées en millimètres.

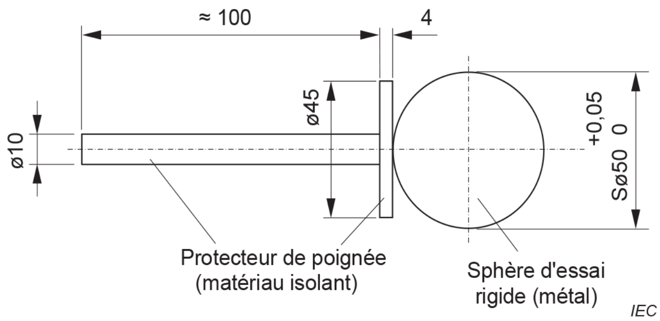
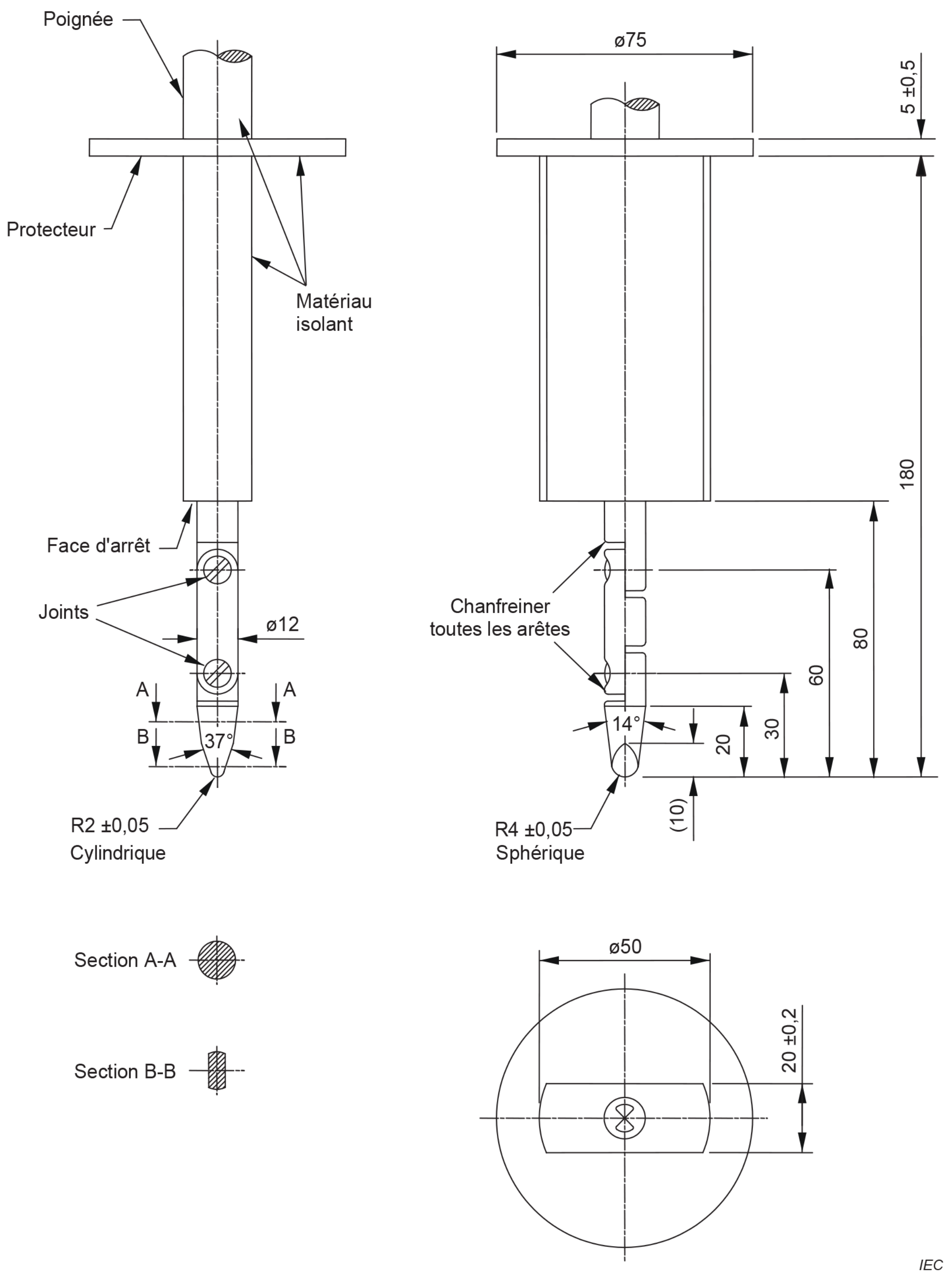


Figure M.1 – Calibre sphérique de 50 mm selon l'IEC 61032:1997, doigt d'essai A



Matériau: métal, sauf spécification contraire.

Tolérance des dimensions sans indication de tolérance:

– sur les angles: –10’

– sur les dimensions linéaires: jusqu’à 25 mm: –0,05 mm; au-dessus de 25 mm: ± 0,2 mm.

Les deux articulations doivent permettre le mouvement dans le même plan et dans la même direction sous un angle de 90° avec une tolérance de 0° à +10°.

Figure M.2 – Doigt d'essai assemblé selon l'IEC 61032:1997, doigt d'essai B

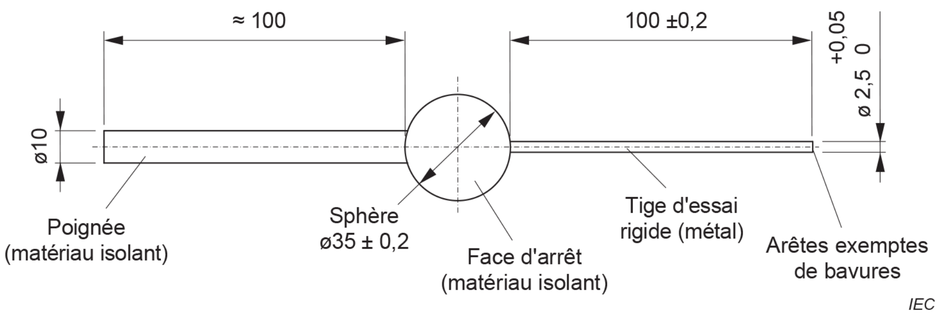


Figure M.3 – Tige d'essai de 2,5 mm selon l'IEC 61032:1997, doigt d'essai C

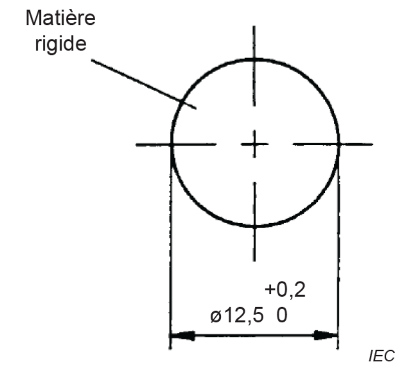


Figure M.4 – Doigt d'essai sphérique de 12,5 mm selon l'IEC 61032:1997, doigt d'essai 2

Annex N
(informative)

Recommandations relatives au courant de court-circuit

Pour plus d'informations, voir l'IEC 62477-1:2022.

Annex O
(informative)

Guide pour la détermination des *distances d'isolement* et des *lignes de fuite*

O.1 Lignes directrices relatives à la détermination des *distances d'isolement*

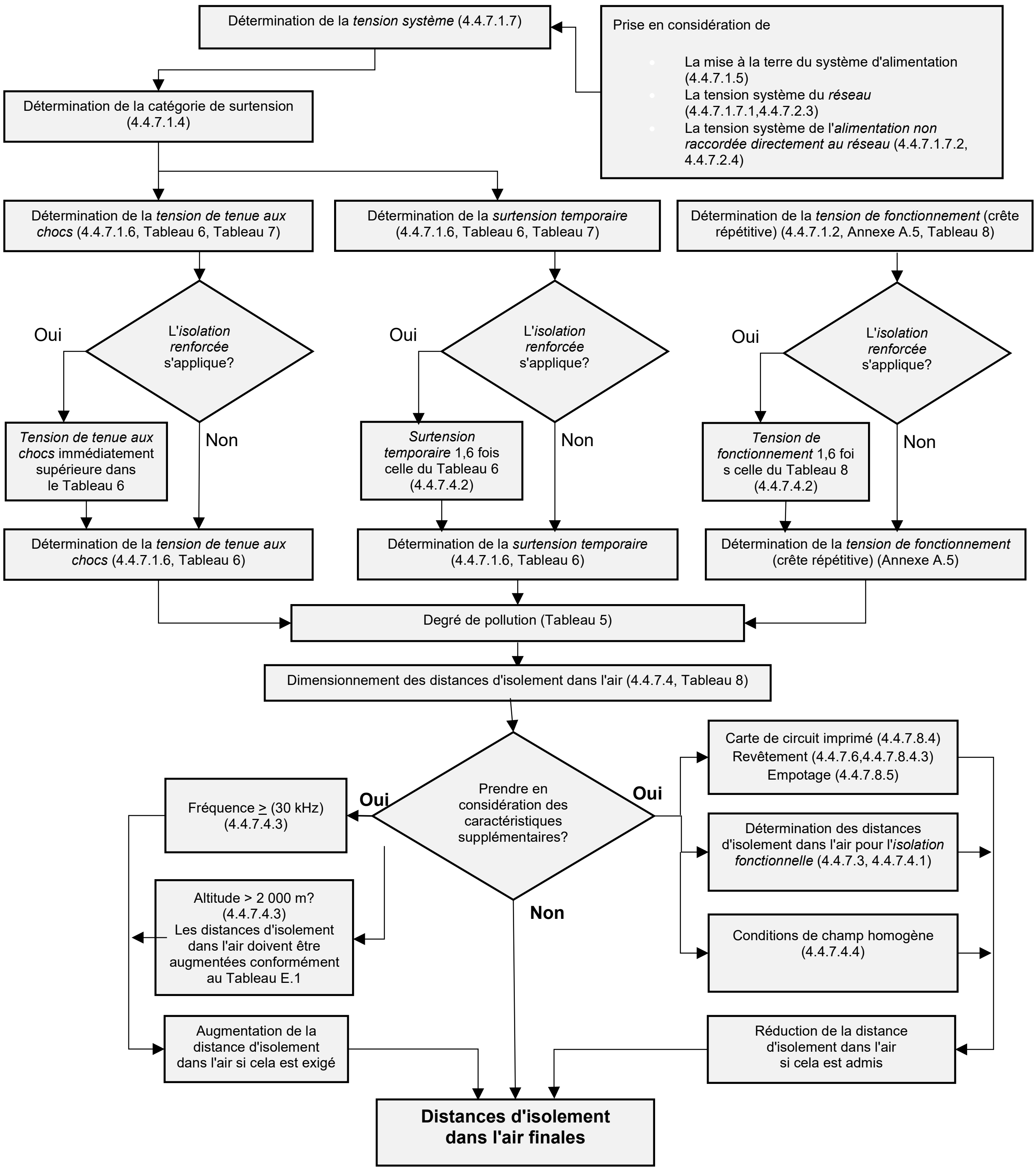


Figure O.1 – Organigramme des *distances d'isolement*

O.2 Lignes directrices relatives à la détermination des *lignes de fuite*

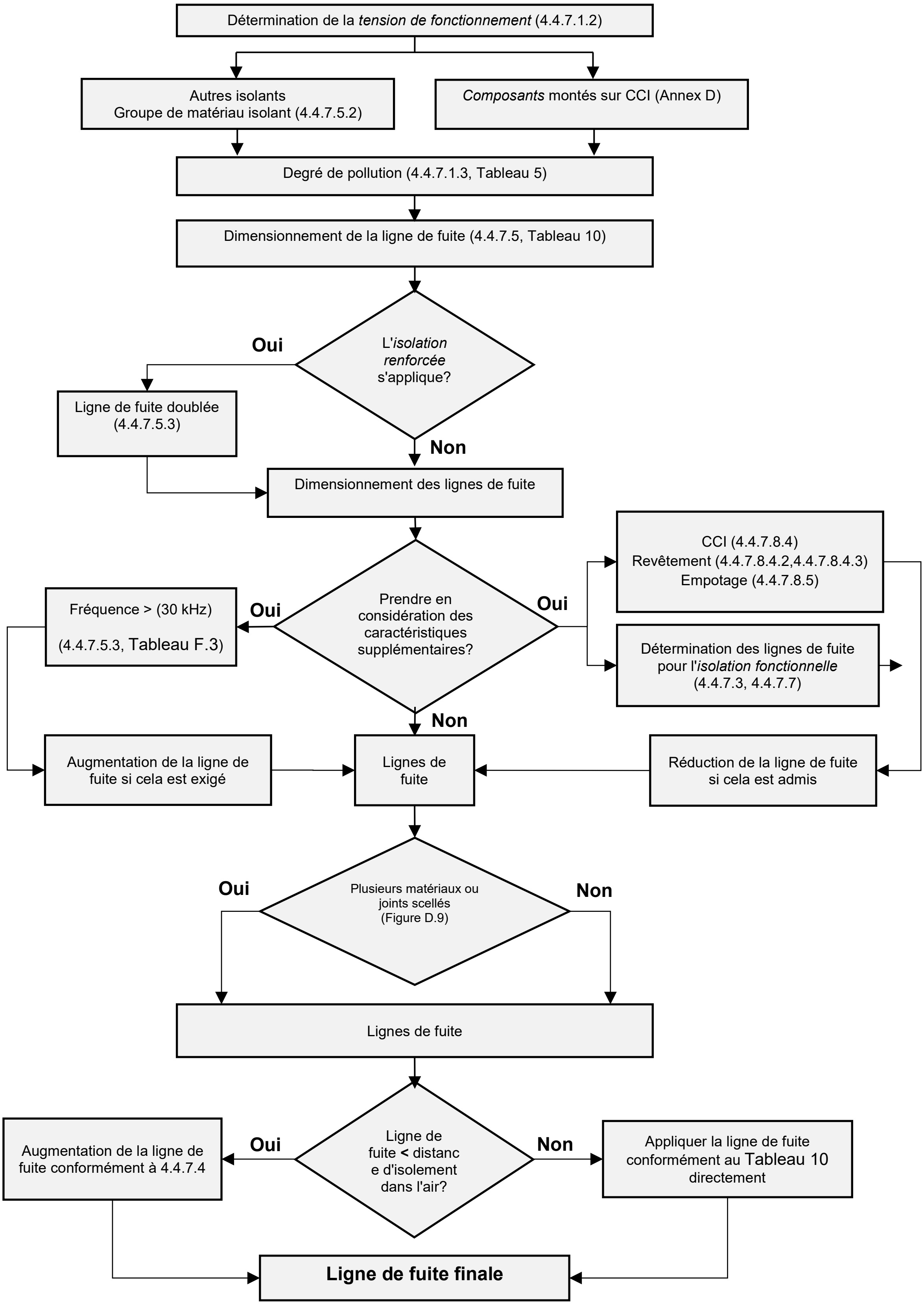


Figure O.2 – Organigramme des *lignes de fuite*

O.3 *Distances d'isolement* et *lignes de fuite* minimales pour le matériau

Source: IEC 60664-3:2016, 4.4.

Pour la protection de type 2 (4.4.7.8.4.3), la couche interne de la carte de circuit imprimé (4.4.7.8.4.2) et les joints scellés (4.4.7.9), les *distances d'isolement* et les *lignes de fuite* entre les conducteurs avant d'appliquer la protection ne doivent pas être inférieures aux valeurs spécifiées dans le Tableau O.1, qui est issu de l'IEC 60664-3:2016, Tableau 1. Ces valeurs s'appliquent à l'*isolation principale*, à l'*isolation supplémentaire* et à l'*isolation renforcée*. Ces valeurs peuvent également s'appliquer à l'*isolation fonctionnelle*.

La valeur de crête maximale déterminée de la tension du 4.4.7.4 (valeur de crête de *surtension temporaire* ou valeur de crête répétitive de la *tension de fonctionnement*) doit être utilisée comme entrée du Tableau O.1.

Tableau O.1 – *Distances d'isolement* et *lignes de fuite* minimales pour le matériau

Valeur de crête maximale d'une tension [a] kV	***Distances d'isolement* et *lignes de fuite* minimales** mm
≤ 0,33	0,01
> 0,33 et ≤ 0,4	0,02
> 0,4 et ≤ 0,5	0,04
> 0,5 et ≤ 0,6	0,06
> 0,6 et ≤ 0,8	0,1
> 0,8 et ≤ 1,0	0,15
> 1,0 et ≤ 1,2	0,2
> 1,2 et ≤ 1,5	0,3
> 1,5 et ≤ 2,0	0,45
> 2,0 et ≤ 2,5	0,6
> 2,5 et ≤ 3,0	0,8
> 3,0 et ≤ 4,0	1,2
> 4,0 et ≤ 5,0	1,5
> 5,0 et ≤ 6,0	2
> 6,0 et ≤ 8,0	3
> 8,0 et ≤ 10	3,5
> 10 et ≤ 12	4,5
> 12 et ≤ 15	5,5
> 15 et ≤ 20	8
> 20 et ≤ 25	10
> 25 et ≤ 30	12,5
> 30 et ≤ 40	17
> 40 et ≤ 50	22
> 50 et ≤ 60	27
> 60 et ≤ 80	35
> 80 et ≤ 100	45

Source: IEC 60664-3:2016, Tableau 1.

L'interpolation linéaire est admise.

[a] Les surtensions transitoires sont ignorées étant donné qu'il est peu probable qu'elles dégradent l'ensemble protégé.

Annex P
(normative)

Protection des personnes contre les champs électromagnétiques pour des fréquences comprises entre 0 Hz et 300 GHz

NOTE L’Annex P a été ajoutée en tant qu'exigence normative pour indiquer la satisfaction aux exigences de la directive européenne basse tension.

P.1 Impact général des champs électromagnétiques sur les personnes

P.1.1 Généralités

(source: Organisation mondiale de la santé, modifiée)

L'exposition aux champs électromagnétique n'a rien d'un phénomène nouveau. Cependant, au cours du 20e siècle, l'exposition environnementale aux champs électromagnétiques générés par l'activité humaine a augmenté régulièrement, parallèlement à la demande d'énergie électrique et les progrès ininterrompus de la technique de même que l'évolution des mœurs ont conduit à la création de sources artificielles de plus en plus nombreuses. Tout le monde est exposé à un ensemble complexe de champs électriques et magnétiques de faible intensité, tant à la maison que sur le lieu de travail. Les sources classiques de champs électromagnétiques vont de la production et du transport de l'électricité pour alimenter les appareils ménagers et les équipements industriels, aux télécommunications et aux émissions radiotélévisées.

Même en l'absence de champs électriques extérieurs, le corps humain est le siège de microcourants dus aux réactions chimiques qui correspondent aux fonctions normales de l'organisme. Par exemple, certains signaux sont relayés par les nerfs sous la forme d'impulsions électriques. Un grand nombre de réactions biochimiques qu'impliquent la digestion et l'activité cérébrale par exemple, comportent une redistribution de particules chargées. Le cœur lui-même est le siège d'une activité électrique que votre médecin peut suivre sur l'électrocardiogramme.

P.1.2 Effets du champ électrique de basse fréquence (1 Hz à 100 kHz)

Les champs électriques de basse fréquence agissent sur l'organisme humain tout comme sur tout autre matériau constitué de particules chargées. En présence de matériaux conducteurs, les champs électriques agissent sur la distribution des charges électriques présentes à leur surface. Ils provoquent la circulation de courants du corps jusqu'à la terre.

P.1.3 Effets du champ magnétique de basse fréquence (1 Hz à 100 kHz)

Les champs magnétiques de basse fréquence font également apparaître à l'intérieur du corps des courants électriques induits. Leur intensité dépend de l'intensité du champ magnétique extérieur. S'ils atteignent une intensité suffisante, ces courants peuvent stimuler les nerfs et les muscles ou induire des sensations visuelles, appelées magnétophosphènes.

P.1.4 Effets du champ électrique et magnétique de basse fréquence

Les champs électriques et magnétiques induisent des tensions et des courants dans le corps, mais même juste en dessous d'une ligne à haute tension, les courants induits sont très faibles comparés aux seuils nécessaires pour produire un choc électrique ou d'autres effets électriques.

P.1.5 Effets du champ électromagnétique de haute fréquence (100 kHz à 300 GHz)

Le principal effet biologique des champs électromagnétiques dont les fréquences sont comprises entre 100 kHz et 300 GHz est un échauffement des tissus. Cette propriété est utilisée dans les fours à microondes pour réchauffer les aliments. Les niveaux des champs de radiofréquences auxquels les personnes sont en principe exposées sont très inférieurs à ceux qui sont nécessaires pour produire une chaleur importante. Les lignes directrices en matière de courant de haute fréquence reposent sur cet effet thermique des ondes radioélectriques.

P.1.6 Connaissances actuelles des effets de faible niveau

Les scientifiques se posent également la question de savoir si, par suite d'une exposition prolongée, des effets peuvent se produire en dessous du seuil d'apparition des effets thermiques. Des organismes d'experts internationaux indépendants estiment que l'ensemble des évaluations de la recherche sur les champs de haute fréquence ne permet pas de conclure que ce type d'exposition sous le seuil thermique provoque des effets sanitaires indésirables.

P.1.7 Effets biologiques/effets sanitaires indésirables

Les effets biologiques sont la réponse mesurable de l'organisme à un stimulus ou à une modification de l'environnement. Ces modifications ne sont pas nécessairement nuisibles à la santé. Par exemple le fait d'écouter de la musique, de lire un livre, de manger une pomme ou de jouer au tennis produit divers effets biologiques. Pourtant, aucune de ces activités n'est présumée provoquer des effets sanitaires indésirables. L'organisme comporte des mécanismes très élaborés qui lui permettent de s'adapter aux influences de notre environnement. Notre vie est faite de changements perpétuels. Mais il est bien entendu que notre organisme ne peut pas compenser intégralement tous les effets biologiques.

Un effet sanitaire indésirable affecte de manière visible la santé du sujet exposé ou de sa descendance, mais un effet biologique peut ou peut ne pas forcément entraîner un effet sanitaire indésirable.

Il est incontestable qu'au-delà de certains niveaux de champs électromagnétiques, certains effets biologiques peuvent se déclencher. Des expériences sur des volontaires en bonne santé prouvent qu'une exposition de courte durée aux niveaux rencontrés dans l'environnement ou à la maison ne produit aucun effet nocif apparent. L'exposition à des niveaux plus élevés et qui peut se révéler dangereuse est limitée par des lignes directrices nationales ou internationales. La question qui fait actuellement débat est celle de savoir si une exposition faible mais prolongée peut susciter des réponses biologiques et nuire au bien-être de la population.

P.1.8 Impact des CEM sur les implants médicaux actifs et passifs

Les champs électromagnétiques peuvent avoir un impact sur les implants médicaux passifs et actifs exposés. Les implants conducteurs passifs peuvent être chauffés par des courants de Foucault induits par des champs extérieurs. Ces champs extérieurs peuvent avoir un impact sur les implants médicaux actifs (les stimulateurs cardiaques, par exemple). Les interférences pouvant avoir des effets même à des niveaux d'exposition inférieurs aux valeurs limites d'exposition du public, la protection des patients équipés d'implants médicaux actifs ou passifs doit faire l'objet de considérations particulières.

P.2 Recommandations issues des Lignes directrices de l'ICNIRP en matière d'exposition aux CEM

P.2.1 Adoption des limites d'expositions données par l'ICNIRP

P.2.1.1 Généralités

Des recommandations relatives à l'exposition de l'homme aux CEM ont été publiées par la Commission internationale sur la protection contre les radiations non ionisantes (ICNIRP – *International Commission on Non-Ionizing Radiation Protection*). Les recommandations de l’Annex P s'appuient sur

- les lignes directrices CEM de l'ICNIRP visant à limiter l'exposition aux champs électriques et magnétiques variables dans le temps (1 Hz à 100 kHz) publiées en 2010 qui indiquent des limites comprises entre 1 Hz et 10 MHz,
- les lignes directrices de l'ICNIRP visant à limiter l'exposition aux champs électriques et magnétiques variables dans le temps (jusqu'à 300 GHz):1998 qui indiquent des limites comprises entre 0 Hz et 300 GHz lorsque des valeurs comprises entre 0 Hz et 1 Hz sont utilisées, et
- la directive européenne 2013/35/UE qui donne les limites de champs magnétiques statiques.

Toutefois, compte tenu de l'expérience fondée sur les essais de CEM, l'émission de champs électromagnétiques supérieurs à 10 MHz n'est pas jugée pertinente pour le *PDS*. L’Annex P donne les limites pour des fréquences comprises entre 0 Hz et 10 MHz.

L'ICNIRP recommande un *système* de valeurs limites en deux étapes. Les restrictions de base de l'ICNIRP et de la directive 2013/35/UE pour l'exposition à basse fréquence reposent sur des champs électriques induits à l'intérieur de l'organisme. Ces restrictions de base font déjà l'objet d'un facteur de sécurité suffisant en ce qui concerne les seuils actuels des effets sanitaires indésirables. Ces restrictions de base n'étant pas mesurables et étant uniquement calculables au prix d'un effort important, l'ICNIRP la directive européenne 2013/35/UE ont déduit des valeurs de référence aisément mesurables en ce qui concerne les champs électriques ou magnétiques extérieurs. La conformité à ces valeurs de référence assure la conformité aux restrictions de base, même dans les situations d'exposition les plus défavorables.

Le concept de sécurité décrit dans l’Annex P repose uniquement sur ces valeurs de référence. Cette spécification ajoute une dose importante de conservatisme aux recommandations déjà conservatrices de l'ICNIRP et à l'approche défendue par la directive européenne 2013/35/UE. De plus, le concept de sécurité décrit dans l’Annex P repose sur les valeurs de référence pour l'exposition de l'ensemble du corps uniquement. La conformité aux valeurs de référence pour l'ensemble du corps implique la conformité à des valeurs de référence moins restrictives pour les membres et les extrémités.

Lorsque les *PDS* sont mis hors tension, aucun champ électromagnétique supérieur aux limites du Tableau P.1 ou du Tableau P.2 n'est prévu, sauf si des aimants permanents font partie intégrante du *PDS*. Dans ce cas, les limites du Tableau P.3 doivent être prises en compte.

P.2.1.2 Limites de CEM pendant le fonctionnement

Les limites du Tableau P.1, du Tableau P.2 et du Tableau P.3 s'appliquent pour une exposition continue.

Si des champs sont générés par des formes d'ondes de commutation à l'intérieur du *PDS*, plusieurs fréquences sont présentes simultanément. Dans ce cas, une sommation de crête pondérée du spectre selon les lignes directrices de l'ICNIRP, ou un équivalent, doit être utilisée pour évaluer l'exposition du champ par rapport à la limite.

NOTE Des procédures équivalentes peuvent être définies dans les règlements nationaux (règlement national DGUV 15 en Allemagne, par exemple).

Tableau P.1 – Limites de CEM pour une exposition de la population générale

Plage de fréquences	**Intensité du champ électrique** kV/m	**Intensité du champ magnétique** A/m	**Induction magnétique** T
0 Hz à 1 Hz [a]	--	$3{,}2 \times 10^{4}$	4×10^{-2}
1 Hz à 8 Hz	5	$3{,}2 \times 10^{4}/f^{2}$	$4 \times 10^{-2}/f^{2}$
8 Hz à 25 Hz	5	$4 \times 10^{3}/f$	$5 \times 10^{-3}/f$
25 Hz à 50 Hz	5	$1{,}6 \times 10^{2}$	2×10^{-4}
50 Hz à 400 Hz	$2{,}5 \times 10^{2}/f$	$1{,}6 \times 10^{2}$	2×10^{-4}
400 Hz à 3 kHz	$2{,}5 \times 10^{2}/f$	$6{,}4 \times 10^{4}/f$	$8 \times 10^{-2}/f$
3 kHz à 10 MHz	$8{,}3 \times 10^{-2}$	21	$2{,}7 \times 10^{-5}$

f en Hz.

Les valeurs sont valables pour l'exposition aux fréquences sinusoïdales.

Les valeurs sont issues des lignes directrices de l'ICNIRP relatives à la limitation de l'exposition à des champs électriques et magnétiques variables dans le temps (1 Hz à 100 kHz) publiées en 2010, Tableau 4.

[a] Les valeurs sont issues des lignes directrices de l'ICNIRP relatives à la limitation de l'exposition à des champs électriques, magnétiques et électromagnétiques variables dans le temps (jusqu'à 300 GHz) publiées en 1998, Tableau 7).

Tableau P.2 – Limites de CEM pour une exposition des travailleurs

Plage de fréquences	Intensité du champ électrique kV/m	Intensité du champ magnétique A/m	Induction magnétique T
0 Hz à 1 Hz [a]	--	$1,63 \times 10^5$	0,2
1 Hz à 8 Hz	20	$1,63 \times 10^5/f^2$	$0,2/f^2$
8 Hz à 25 Hz	20	$2 \times 10^4/f$	$2,5 \times 10^{-2}/f$
25 Hz à 300 Hz	$5 \times 10^2/f$	8×10^2	1×10^{-3}
300 Hz à 3 kHz	$5 \times 10^2/f$	$2,4 \times 10^5/f$	$0,3/f$
3 kHz à 10 MHz	$1,7 \times 10^{-1}$	80	1×10^{-4}

f en Hz.

Les valeurs sont valables pour l'exposition aux fréquences sinusoïdales.

Les valeurs sont issues des lignes directrices de l'ICNIRP relatives à la limitation de l'exposition à des champs électriques et magnétiques variables dans le temps (1 Hz à 100 kHz) publiées en 2010, Tableau 3).

[a] Les valeurs sont issues des lignes directrices de l'ICNIRP relatives à la limitation de l'exposition à des champs électriques, magnétiques et électromagnétiques variables dans le temps (jusqu'à 300 GHz) publiées en 1998, Tableau 6).

Tableau P.3 – Limites pour une induction magnétique de champs magnétiques statiques

Dangers potentiels	Induction magnétique mT
Interférence avec des dispositifs actifs implantés, par exemple des stimulateurs cardiaques	0,5
Risque d’attraction et de projection dû aux aimants permanents	3

Les valeurs sont issues de la directive européenne 2013/35/UE, Tableau B4.

P.2.2 Limites d'exposition aux CEM pour le transport et le stockage

Pendant le transport et le stockage, le *BDM/CDM/PDS* est mis hors tension. Les limites du Tableau P.3 peuvent toujours s'appliquer.

Des informations doivent être données pour assurer la sécurité des personnes:

- la distance exigée dans l'emballage du produit et sans l'emballage; ou
- d'autres moyens.

P.3 Protection des personnes contre l'exposition aux CEM

P.3.1 Généralités

À l'Article P.3, les limites de l'ICNIRP dans l'Article P.2 sont adoptées pour correspondre aux conditions du *PDS*.

Les conditions suivantes doivent être prises en compte:

- conditions normales de fonctionnement et *conditions anormales de fonctionnement* dans
  - les zones d'accès du public, et

  – les *zones d'accès général,* les *zones d’accès pour la maintenance* et les *zones d'accès limité*;
- les implants médicaux passifs et actifs;
- le transport et le stockage.

Pour les exigences, voir P.3.2, P.3.3 ou P.3.4.

Pour la conformité, voir P.4.2.

Pour le marquage, voir l’Article P.5.

P.3.2 Exigences de CEM pour les zones d'accès du public

Dans des conditions normales de fonctionnement et dans des *conditions anormales de fonctionnement*, les *PDS* sous enveloppe enfichables destinés à être utilisés dans des zones d'accès du public ne doivent pas dépasser les limites du

a) Tableau P.1 pour protéger les personnes équipées ou non d'implants passifs, et

b) Tableau P.3 pour protéger les personnes équipées d'implants médicaux (stimulateurs cardiaques).

NOTE Dans certains pays, des limites individuelles sont établies. En Allemagne, par exemple, elles sont de 0,1 mT/50 Hz pour les implants médicaux actifs dans 26. BImschV (Bundesimmisionsschutz Verordnung der Bundesrepublik Deutschland).

Les limites sont valables à une distance de 0 cm de la surface du *BDM/CDM/PDS*.

Pour les *PDS connectés en permanence,* des moyens peuvent être exigés dans la documentation pour satisfaire aux exigences.

P.3.3 Exigences de CEM pour les *zones d'accès général*, les *zones d'accès pour la maintenance* et les *zones d'accès limité*

Dans des conditions normales de fonctionnement et dans des *conditions anormales de fonctionnement*, les *PDS* sous enveloppe destinés à être utilisés dans des *zones d'accès général*, dans des *zones d'accès pour la maintenance* et dans des *zones d'accès limité* ne doivent pas dépasser les limites du

- Tableau P.2 pour protéger les personnes équipées ou non d'implants passifs, et
- Tableau P.3 pour protéger les personnes équipées d'implants médicaux (stimulateurs cardiaques), le cas échéant.

Les limites sont valables à une distance de 25 cm de la surface.

NOTE La distance est choisie selon l'EN 12198-1:2000 et l'EN 12198-1:2000/AMD1:2008, Article B.4.

Pour les *BDM/CDM* de *type ouvert*, les informations relatives aux moyens de protection doivent être données dans la documentation (utiliser des armoires d'appareillage de connexion en métal non ferreux ou la distance, par exemple).

Pour le marquage, voir l'Article P.5.

P.3.4 Exigences de CEM pour le transport et le stockage

Pendant le transport et le stockage, le *PDS* est mis hors tension. Toutefois, les limites du Tableau P.3 s'appliquent lorsque des aimants permanents font partie intégrante du *PDS*.

Les limites sont valables à une distance de 25 cm de la surface non emballée ou à une distance de 0 cm de la surface de l'emballage.

Si des distances plus importantes sont exigées, cela doit être indiqué dans la documentation.

NOTE 1 La distance est choisie selon l'EN 12198-1:2000 et l'EN 12198-1:2000/AMD1:2008, Article B.4.

La force due aux champs magnétiques statiques doit être prise en compte.

NOTE 2 Une source de champs magnétiques statiques est, par exemple, un moteur linéaire ou un simple *composant* magnétique.

P.4 Essai de champs électromagnétiques (CEM) (*essai de type*)

P.4.1 Montage général d'essai pour les CEM

Lorsque cela est exigé en P.3.2, en P.3.3 ou en P.3.4, le calcul, la simulation ou les essais selon le Tableau P.4 doivent être réalisés à une distance du sol permettant de couvrir le corps de la personne à protéger, et le *PDS* est mis sous tension afin de démontrer la satisfaction aux exigences.

La durée de mesure ne doit pas être inférieure à 1 s à une distance spécifiée en P.3.2, en P.3.3 ou en P.3.4 applicable. Il est admis d'utiliser des capteurs de crête pondérée pour le moyennage de 100 cm^2.

Dans les applications connues, la durée classique de présence physique des personnes peut être prise en compte.

Voir l'IEC 62311 ou l'EN 12198 (toutes les parties) pour des informations complémentaires.

P.4.2 Essai CEM

Le calcul, la simulation ou les essais doivent être réalisés selon le Tableau P.4.

Tableau P.4 – Vue d'ensemble des essais CEM

Zone d'accès	Exigences	Autres moyens admis
Zones d'accès du public	Tableau P.1 et Tableau P.3	Non
Zones d'accès général, zones d'accès pour la maintenance et *zones d'accès limité*	Tableau P.2 et Tableau P.3	Oui (distances ou durée d'exposition, par exemple)
Transport et stockage	Tableau P.3	Oui (distances ou durée d'exposition, par exemple)

P.5 Marquage des champs électromagnétiques (CEM)

Lorsque cela est exigé en P.3.1, en P.3.2, ou en P.3.3, le *BDM/CDM/PDS* doit être marqué du symbole d'avertissement ISO 7010-W001:2011-05 ou ISO 7000-0434a:2004-01 ou ISO 7000-0434b:2004-01 (voir le Tableau C.1) et la documentation doit donner les informations suivantes.

Pour le fonctionnement:

- le niveau de protection annoncé selon le Tableau P.1, le Tableau P.2 ou le Tableau P.3; ou
- les autres moyens exigés dans l'*installation*, par exemple, distance ou durée d'exposition.

Pour le transport et le stockage:

- les distances exigées dans l'emballage du produit et sans l'emballage; ou
- les autres moyens exigés; et
- les informations relatives à la manutention, en raison de la force générée par le champ magnétique statique.

Annex Q
(informative)

Déconnexion automatique de l'alimentation

Q.1 Temps de déconnexion maximal

Pour plus d'informations, les paragraphes 411.3.2.2, 411.3.2.3, 411.3.2.4, 415.2.1 et 415.2.2 ont été reproduits de l'IEC 60364-4-41:2005 et l'IEC 60364-4-41:2005/AMD1:2017.

NOTE La numérotation des articles de la présente Annex Q est issue de la norme source et ne peut pas être modifiée.

411.3.2 Déconnexion automatique en cas de défaut

411.3.2.1 Un dispositif de protection doit automatiquement couper l'alimentation du conducteur de ligne d'un circuit ou d'un équipement en cas de défaut d'impédance négligeable entre le conducteur de ligne et une partie conductrice exposée ou un conducteur de protection, dans les limites du temps de déconnexion exigé en 411.3.2.2, 411.3.2.3 ou 411.3.2.4.

Le dispositif doit être adapté pour l'isolation d'au moins le ou les conducteurs de ligne.

411.3.2.2 Le temps de déconnexion maximal indiqué dans le Tableau 41.1 doit être appliqué aux circuits finaux dont le courant assigné ne dépasse pas

- 63 A avec un ou plusieurs socles de prise de courant, et
- 32 A alimentant uniquement les équipements d'utilisation connectés fixes.

NOTE 1 Dans l'IEC 60364-4-41, le terme "connecté fixe" est l'équivalent de "*connectés en permanence*" du présent document.

NOTE 2 Dans le présent document, le terme "conducteur de protection" est l'équivalent de "*conducteur de mise à la terre de protection*".

NOTE 3 Dans le présent document, le terme "ligne" est l'équivalent de "phase".

Tableau 41.1 – Temps de déconnexion maximaux

Système	50 V < U_o ≤ 120 V s		120 V < U_o ≤ 230 V s		230 V < U_o ≤ 400 V s		U_o > 400 V s	
	Courant alternatif	Courant continu	Courant alternatif	Courant continu	Courant alternatif	Courant continu	Courant alternatif	Courant continu
TN	0,8	--[a]	0,4	1	0,2	0,4	0,1	0,1
TT	0,3	--[a]	0,2	0,4	0,07	0,2	0,04	0,1

Si, dans des systèmes TT, la déconnexion est assurée par un dispositif de protection contre les surintensités et que la *liaison équipotentielle de protection* est reliée aux parties conductrices parasites à l'intérieur de l'installation, les temps de déconnexion maximaux applicables aux systèmes TN peuvent être utilisés.

U_o est la tension phase-terre alternative ou continue nominale.

NOTE Si la déconnexion est assurée par un DDR, voir NOTE jusqu'à 411.4.4, NOTE 4 à 411.5.3 et NOTE jusqu'à 411.6.4 b).

[a] La déconnexion peut être exigée pour d'autres raisons que la protection contre les chocs électriques.

411.3.2.3 Dans les systèmes TN, un temps de déconnexion qui ne dépasse pas 5 s est admis pour les circuits de distribution et pour les circuits non couverts par 411.3.2.2.

411.3.2.4 Dans les systèmes TT un temps de déconnexion qui ne dépasse pas 1 s est admis pour les circuits de distribution et pour les circuits non couverts par 411.3.2.2.

Q.2 *Liaison équipotentielle de protection* supplémentaire

NOTE 1 La *liaison équipotentielle de protection* supplémentaire est considérée comme un ajout à la protection en cas de défaut.

NOTE 2 L'utilisation de la liaison de protection supplémentaire ne dispense pas du besoin de déconnecter l'alimentation pour d'autres raisons, par exemple pour la protection contre le feu, la contrainte thermique dans l'équipement, etc.

NOTE 3 La liaison de protection supplémentaire peut impliquer une installation complète, une partie de l'installation, un élément d'un appareil ou un emplacement.

NOTE 4 Des exigences supplémentaires peuvent s'avérer nécessaires pour les emplacements particuliers (voir la partie correspondante de la série IEC 60364-7) ou pour d'autres raisons.

415.2.1 La *liaison équipotentielle de protection* supplémentaire doit inclure toutes les parties accessibles exposées accessibles simultanément de l'équipement fixe et les parties conductrices parasites y compris, le cas échéant, l'armature métallique du béton armé de construction. Le système de liaison équipotentielle doit être relié aux conducteurs de protection de tous les équipements, y compris à ceux du socle de prise de courant.

NOTE 1 Dans l'IEC 60364-4-41, le terme "connecté fixe" est l'équivalent de "*connectés en permanence*" du présent document.

NOTE 2 Dans le présent document, le terme "conducteur de protection" est l'équivalent de "*conducteur de mise à la terre de protection*".

NOTE 3 Dans le présent document, le terme "partie conductrice exposée" est l'équivalent de "*partie accessible* conductrice".

NOTE 4 Une "partie conductrice parasite" est "une partie conductrice de l'équipement qui peut être touchée et qui n'est pas une *partie active*, mais qui peut le devenir dans les conditions d'erreur".

415.2.2 La résistance *R* entre les parties conductrices exposées accessibles simultanément et les parties conductrices parasites doit satisfaire à la condition suivante:

$$R \leq \frac{50\ \text{V}}{I_\text{a}} \quad \text{dans les systèmes en courant alternatif}$$

$$R \leq \frac{120\ \text{V}}{I_\text{a}} \quad \text{dans les systèmes en courant continu}$$

où

I_a est le courant de fonctionnement en A du dispositif de protection:

- pour les dispositifs de protection à courant différentiel résiduel (DDR), $I_{\Delta\text{n}}$;
- pour les dispositifs de protection contre les surintensités, le courant de fonctionnement de 5 s.

Annex R
(informative)

Appréciation du risque selon le Guide IEC 116

R.1 Généralités

La présente Annex R a pour objet de donner à l'utilisateur du présent document un aperçu des dangers potentiels selon le Guide IEC 116.

Cet aperçu peut s'avérer utile pour l'utilisateur lors de l'évaluation du risque selon 4.2.

En présence d'un danger dont l'atténuation du risque n'est pas couverte par le présent document, il convient de lire d'autres normes, publications ou documents de référence décrivant l'état de la technique disponible.

R.2 Appréciation du risque

Le Tableau R.1 donne une vue d'ensemble de l'appréciation du risque.

Tableau R.1 – Appréciation du risque

Exigence	Pertinente oui/non?	Satisfaite par
A.2 Observations préliminaires	Oui	Application du Guide IEC 116:2018, Annexe A
A.3 Intégration de sécurité	Oui	Application du Guide IEC 116, et de la "méthodologie en 3 étapes" en particulier: – mesures de conception inhérentes; – mesures de protection; – informations de l'utilisateur.
A.4 Protection contre les dangers électriques		4.1, 4.2, 4.4, 4.5, 4.8, 4.9, 4.11, 4.12, 4.13, Annex A, Annex D, Annex E, Annex F, Annex M
Courant de fuite	Oui	4.4.4.3.3, 4.4.5.4, 4.4.8
Alimentation en énergie	Oui	4.4.7.1 à 4.4.7.2, 4.8
Charges emmagasinées	Oui	4.4.9, 4.5
Arcs	Oui	4.4.7.8.2
Choc électrique	Oui	4.1, 4.2, 4.4, 4.5, 4.8, 4.9, 4.11, 4.12, 4.13, Annex A, Annex D, Annex E, Annex F, Annex M
Brûlures (courant continu et haute fréquence)	Oui	4.4.4.4, 4.4.5.4
A.5 Protection contre les dangers mécaniques		4.1, 4.2, 4.7, 4.9, 4.12
Instabilité	Oui	4.12.5
Rupture pendant le fonctionnement	Oui	4.12.1 à 4.12.4
Chute ou éjection d'objets	Oui	4.4.4.3.3, 4.7.5.3
Surfaces, bords ou coins inadaptés	Oui	4.7.6
Parties mobiles, en particulier lorsqu'il peut y avoir des variations dans la vitesse de rotation des pièces	Oui	4.7.5.2
Vibrations	Oui	4.9
Fixation incorrecte des pièces	Oui	4.11.6

Exigence	Pertinente oui/non?	Satisfaite par
A.6 Protection contre d'autres dangers		4.1, 4.2, 4.10, 4.14
A.6.2 Explosion	Non	
A.6.3 Dangers dus aux champs électriques, magnétiques et électromagnétiques, à d'autres rayonnements ionisants et non ionisants	Oui	4.14
A.6.4 Perturbations électriques, magnétiques et électromagnétiques	Oui	Non couvert
A.6.5 Rayonnement optique	Non	
A.6.6 Feu	Non	
A.6.6.1 Rupture de *composant* (*condition de premier défaut*)	Oui	4.2, 4.5.3
A.6.6.2 Protection contre les courts-circuits et les surcharges (*condition de premier défaut*)	Oui	4.2, 4.3
A.6.7 Température	Oui	4.6.5
A.6.8 Bruit acoustique	Oui	4.10
A.6.9 Effets biologiques et chimiques	Oui	4.9
A.6.10 Émissions, production et/ou utilisation de substances dangereuses (gaz, liquides, poussières, brouillards, vapeur, par exemple)	Non	
A.6.11 Fonctionnement intempestif	Oui	Annex A
A.6.12 Connexion à l'alimentation et interruption	Oui	4.2, 4.3, 4.4.4.4, 4.4.8, 4.8, 4.11
A.6.13 Combinaison d'équipements	Oui	4.1, 4.2, 4.4.2.3
A.6.14 Implosion	Non	
A.6.15 Conditions d'hygiène	Non	
A.6.16 Ergonomie	Non	
A.7 Sécurité fonctionnelle et fiabilité	Non	
A.7.2 Conception de l'équipement	Non	
A.7.3 Dangers liés au type	Non	
A.7.4 Défauts du *système*	Non	
A.8 Sécurité liée à la sûreté	Non	
Attribuer les exigences 1) à 3) aux catégories a) à d) en tenant compte des exigences fondamentales I. à V.	Non	
a) Protection contre les violations occasionnelles	No	
b) Protection contre les violations volontaires à l'aide de moyens simples à faibles ressources, compétences génériques et faible motivation	Non	
c) Protection contre les violations volontaires à l'aide de moyens sophistiqués avec des ressources modérées, des compétences spécifiques liées à l'équipement considéré et une motivation modérée	Non	
d) Protection contre les violations volontaires à l'aide de moyens sophistiqués avec des ressources étendues, des compétences spécifiques liées à l'équipement considéré et une motivation importante	Non	
A.9 Exigences d'informations	Oui	6.1 à l'Annex A
NOTE Ce tableau est issu du Guide IEC 116:2018, Tableau D.1.		

Annex S
(informative)

Exigences inhérentes à certains pays – États-Unis Tensions inférieures à 1,5 kV en courant alternatif ou en courant continu

S.0 Généralités

Les articles suivants s'appliquent aux *BDM/CDM/PDS* destinés à être installés aux États-Unis. Ces exigences viennent en complément, modifient, remplacent ou suppriment (rendent inapplicables) les exigences des parties principales du présent document. Sauf indication contraire, ces exigences viennent en complément des exigences d'origine du présent document. Les exigences des parties principales du présent document qui ne sont pas référencées dans l'Annex S s'appliquent en l'état. La liste actuelle et exhaustive des différences nationales pour les États-Unis est publiée dans la dernière édition et révision de l'UL 61800-5-1.

Les articles de l'Annex S suivent la numérotation du corps du document. La structure principale du présent document est transposée dans la présente Annex S et les titres sont insérés sous la forme de liens actifs permettant d'atteindre facilement le texte IEC applicable. Chaque élément numéroté supplémentaire est numéroté à partir de 200.

NOTE Les différences nationales de l'Annex S pour les Etats-Unis sont incluses avec l'autorisation de l'UL et s'appuient sur l'UL 61800-5-1, Éd. 1., révision du 24 février 2017, et dans certains cas révisée en raison de modifications apportées aux exigences normatives entre IEC 61800-5-1:2007 et le présent document.

S.1 Domaine d'application

Ajout à l'Article 1:

Le domaine d'application se limite aux entraînements électriques de puissance à vitesse variable destinés à alimenter un ou plusieurs moteurs à partir d'un *BDM* relié à des tensions entre phases allant jusqu'à 1,5 kV inclus en courant alternatif (50 Hz ou 60 Hz) et/ou jusqu'à 1,5 kV inclus en courant continu.

Le domaine d'application se limite aux *BDM/CDM/PDS* à installer dans des emplacements ordinaires conformément à l'Article 430 et à l'Article 440 du National Electrical Code, ANSI/NFPA 70.

Un *composant* d'un produit couvert par le présent document doit satisfaire aux exigences de ce *composant*. Voir l'Article S.201 pour une liste de normes supplémentaires couvrant les *composants* utilisés dans les produits eux-mêmes couverts par le présent document.

Le présent document s'applique uniquement à la conversion de puissance et aux équipements de commande des *BDM/CDM*, aux servo *BDM/CDM* et aux combinaisons intégrales de servo *BDM/CDM* /servomoteur.

S.2 Références normatives

Ajout à l'Article 2:

Voir l'Article S.201 pour les références normatives et les normes de *composants* aux États-Unis. Voir l'Article S.202 pour les références normatives IEC qui ne s'appliquent pas et celles qui sont remplacées par des normes américaines.

S.3 Termes et définitions

Ci-après sont donnés des termes et définitions supplémentaires applicables aux États-Unis d'Amérique ou un ajout des termes existants, selon ce qui est applicable aux États-Unis d'Amérique.

S.3.46
basse tension

Addition:

Note 1 à l'article: BDM/CDM/PDS fonctionnant à plus de 600 V en courant alternatif est considéré comme un *BDM/CDM/PDS haute tension* selon les exigences du National Electrical Code, ANSI/NFPA 70.

S.3.47
BDM/CDM/PDS basse tension

Addition:

Note 1 à l'article: BDM/CDM/PDS fonctionnant à plus de 600 V en courant alternatif n'est pas considéré comme un *BDM/CDM/PDS basse tension* selon les exigences du National Electrical Code, ANSI/NFPA 70.

Termes et définitions supplémentaires:

S.3.200
installation de groupe
circuit de branchement d'un moteur pour au moins deux moteurs avec d'autres charges, protégé par un disjoncteur ou un seul ensemble de fusibles

S.3.201
partie active isolée
partie active d'un point de vue électrique, comportant une protection complète contre les chocs électriques et qui ne compte pas sur d'autres parties pour assurer l'isolation

S.4 Protection contre les dangers

S.4.1 Généralités

Ajout à 4.1:

Un *BDM/CDM* doit être construit de manière à satisfaire aux règles d'installation et d'utilisation du National Electrical Code, ANSI/NFPA 70.

Pour les circuits secondaires isolés, les exigences du S.203.1 peuvent être utilisées pour déterminer si l'une des exigences en matière de risque de dangers de choc électrique, de dangers thermiques ou de dangers énergétiques peut être ignorée.

S.4.2 *Conditions de* premier *défaut et conditions anormales de fonctionnement*

Ajout à 4.2:

L'analyse doit inclure la Classe 2, la tension/le courant secondaire limité ou les circuits à impédance de limitation comme cela est défini en S.203.1 uniquement si une défaillance du *composant* dans le circuit crée un danger dans un circuit qui n'est pas alimenté par le circuit secondaire isolé.

S.4.3 Protection contre les courts-circuits et les surcharges

S.4.3.1 Généralités

Ajout à 4.3.1:

Le nombre, la disposition et les caractéristiques assignées ou les réglages des dispositifs de protection destinés à assurer la protection en cas de défaut à la terre et les courts-circuits du circuit de dérivation du moteur doivent satisfaire aux exigences de la Partie IV, Article 430 du National Electrical Code, ANSI/NFPA 70.

L'IEC 60364-4-41:2005 et l'IEC 60364-4-41:2005/AMD1:2017, 411.3.2, et l'IEC 60364-4-41:2005 et l'IEC 60364-4-41:2005/AMD1:2017, 415.2 ne s'appliquent pas aux États-Unis d'Amérique.

S.4.3.2 Valeurs assignées de court-circuit en *entrée et courant* disponible *de court-circuit en sortie*

S.4.3.2.1 Généralités

S.4.3.2.2 Courant *conditionnel assigné de* court-circuit (I_{cc}) sur les accès de puissance d'entrée

Ajout à 4.3.2.2:

Pour se coordonner avec les dispositifs de protection en amont, le fabricant doit spécifier une valeur assignée maximale *de courant de court-circuit présumé*. La caractéristique assignée du *courant de court-circuit présumé* ne doit pas être inférieure au courant spécifié dans le Tableau 36 en fonction de la caractéristique assignée en sortie du courant à pleine charge du *BDM/CDM*. Pour un *BDM/CDM* adapté uniquement en cheval-vapeur et pas en courant, la caractéristique assignée équivalente cheval-vapeur doit être telle que spécifiée dans le Tableau S.29 et l'Article S.204.

Une série *BDM/CDM* doit satisfaire à l'essai de court-circuit – courants de défaut élevés, S.5.2.4.2.202, et à l'essai de court-circuit – courants de défaut normalisés, 5.2.4.5, s'il est destiné à être utilisé avec

a) une valeur de courant de défaut normalisée selon le Tableau 36, et
b) une valeur de courant de défaut élevée supérieure à la valeur de courant de défaut normalisée.

Une série *BDM/CDM* satisfait à l'essai de court-circuit – courants de défaut élevés, S.5.2.4.2.202, sans essai supplémentaire lorsque

c) la série *BDM/CDM* utilise un *circuit électronique de protection contre les courts-circuits en sortie de puissance* pour la conformité à l'essai de court-circuit de courant de défaut normalisé, et
d) le *circuit électronique de protection contre les courts-circuits en sortie de puissance* est utilisé selon les points e) à k) -dessous.

Tout modèle peut servir de modèle représentatif à partir d'une série qui utilise un *circuit électronique de protection contre les courts-circuits en sortie de puissance* pour satisfaire à cet essai. Par exemple, pour une série *BDM/CDM* avec des modèles adaptés entre 25 hp et 700 hp (18,64 kW à 521,99 kW), l'essai du modèle 25 hp à 5 000 A représente l'essai de modèles à 10 000 A, 18 000 A, 30 000 A, ou 42 000 A. De plus, l'essai de court-circuit peut être réalisé à 5 000 A afin de représenter des valeurs d'essai de court-circuit supérieures lorsque toutes les exigences suivantes sont satisfaites.

e) Le même circuit de protection à semiconducteurs est utilisé dans toute la série.
f) Toutes les révisions du circuit de protection exigent une réévaluation.

g) Le circuit de protection désactive les dispositifs de sortie (transistor bipolaire à grille isolée (IGBT), dispositifs bipolaires et analogues) avant qu'ils ne soient endommagés par une augmentation du courant. Cela s'appuie sur les caractéristiques assignées des dispositifs de sortie indiquées par le fabricant (en règle générale 10 µs pour les IGBT et 50 µs pour les dispositifs bipolaires).

h) Toute augmentation du courant à laquelle sont confrontés les dispositifs de sortie est le résultat de la décharge de la batterie de condensateurs de bus à courant continu.

i) Les dispositifs de sortie sont désactivés par le circuit de protection avant une augmentation significative du courant d'entrée.

j) En réponse à un courant de défaut normalisé plus élevé (42 000 A VS 5 000 A, par exemple), le circuit de protection doit réagir au courant de défaut normalisé plus élevé (42 000 A) dans un temps égal ou plus court que pour le courant de défaut normalisé moins élevé (5 000 A). Cela peut être vérifié dans le cadre d'un essai réalisé à la valeur de courant de défaut maximale ou par l'*inspection visuelle* du 5.2.1 du matériel et du logiciel du *circuit électronique de protection contre les courts-circuits en sortie de puissance*.

k) Si un dispositif de détection de courant (par opposition au dispositif de détection de la tension du collecteur du dispositif de sortie) est utilisé pour actionner le circuit de protection, le bus à courant continu ou toutes les lignes de sortie du moteur principal doivent être surveillé(e)s.

Un *BDM/CDM* qui n'utilise pas uniquement une protection statique contre les courts-circuits doit également satisfaire aux exigences de facteur de puissance de l'essai de court-circuit de l'UL 60947-4-1.

S.4.3.3 Coordination de court-circuit (protection en amont)

Ajout à 4.3.3:

Voir S.4.3.2.1 pour plus d'informations relatives à la coordination de court-circuit.

S.4.3.4 Protection par plusieurs dispositifs

S.4.3.5 Protection contre la surchauffe et contre les surcharges du moteur

S.4.3.5.1 Moyens de protection

Ajout à 4.3.5.1:

Le nombre, la disposition et les caractéristiques assignées ou les réglages des dispositifs de protection destinés à assurer la protection contre les surcharges du moteur et du circuit de dérivation doivent satisfaire aux exigences de la Partie III, Article 430 du National Electrical Code, ANSI/NFPA 70.

S.4.3.5.2 *BDM/CDM* avec *protection électronique contre les surcharges du moteur*

Ajout à 4.3.5.2:

Une *protection électronique contre les surcharges du moteur* réglable peut être réglée de manière à dépasser la limite de 1,2 fois le courant de réglage avec un délai de déclenchement de 2 h du Tableau 37. Toutefois, la limite de 1,25 fois le courant de réglage avec un délai de déclenchement de 2 h ne doit pas être dépassée.

S.4.4 Protection contre les chocs électriques

S.4.4.1 Généralités

S.4.4.2 *Classe de tension déterminante (CTD)*

S.4.4.3 Dispositions en matière de *protection principale*

S.4.4.3.1 Généralités

S.4.4.3.2 Protection au moyen de l'isolation *principale* des *parties actives dangereuse*

S.4.4.3.3 Protection au moyen d'enveloppes ou de barrières

Remplacement du 4.4.3.3:

L'accessibilité des *parties actives* des circuits *CTD B* ou *CTD C*, à l'exclusion des circuits secondaires isolés de la *CTD B* qui ont été examinés en S.203 qui n'exigent pas de protection contre le contact direct comme cela est indiqué dans le Tableau S.28, doit être déterminée conformément aux exigences mécaniques relatives aux enveloppes du S.4.12.

S.4.4.4 Dispositions en matière de *protection en cas de défaut*

S.4.4.4.1 Généralités

S.4.4.4.2 *Liaison équipotentielle de protection*

S.4.4.4.2.1 Généralités

Modification du 4.4.4.2.1:

Le point b) du 4.4.4.2.1 ne s'applique pas.

Paragraphe supplémentaire au 4.4.4.2:

S.4.4.4.2.200 Liaison

Outre ce qui est indiqué dans l'alinéa suivant, une *enveloppe* constituée d'un matériau isolant, en tout ou partie, doit comporter des moyens de liaison afin d'assurer la continuité de la mise à la terre entre toutes les ouvertures de conduite. Les moyens de liaison doivent être complètement assemblés sur le produit ou être fournis en pièces détachées pour une installation sur site.

Un moyen de liaison n'est pas exigé pour une *enveloppe* destinée à être reliée à un seul conduit. Les *enveloppes* doivent être marquées selon S.6.3.9.200.

Il n'est pas exigé de fournir un moyen de liaison avec chaque *enveloppe* lorsque ledit moyen se présente sous la forme d'un kit proposé par le fabricant et que le *BDM/CDM/PDS* satisfait aux exigences de marquage du S.6.3.9.200.

Outre ce qui est indiqué dans l'alinéa suivant, la continuité d'un *système* de conduit doit être assurée par un contact métal sur métal sans matériau polymère.

Il n'est pas interdit que la continuité du *système* de mise à la terre repose sur l'intégrité de l'*enveloppe* polymère lorsque les échantillons ont été soumis à l'essai de fluage de l'UL 746C. Les essais de surintensité doivent être réalisés à 200 % du courant assigné du dispositif de protection du circuit de dérivation.

Un conducteur de liaison séparé installé dans une enveloppe en plastique ou en métal doit être en cuivre, en alliage de cuivre ou autre matériau dont il a été déterminé qu'il peut servir de conducteur électrique. Les parties en métal ferreux dans le trajet de mise à la terre doivent être protégées contre la corrosion par émaillage, galvanisation, plaquage ou d'autres moyens équivalents. Un conducteur de liaison séparé

a) doit être protégé contre les dommages mécaniques ou être placé à l'intérieur de l'*enveloppe* extérieure ou du châssis, et

b) ne doit pas être fixé par un une fixation amovible utilisée pour tout autre chose que la liaison, sauf si le conducteur de liaison ne peut pas être ignoré après le retrait et le remplacement de la fixation.

Outre ce qui est indiqué dans l’alinéa suivant, la dimension d'un conducteur de liaison de *composant* séparé ne doit pas être inférieure à la dimension applicable spécifiée dans le Tableau S.1 ou à la dimension du conducteur qui alimente le *composant*, si celle-ci est plus petite.

Il n'est pas exigé qu'un conducteur de liaison soit aussi large que celui spécifié dans l’alinéa ci-dessus

c) s'il ne s'ouvre pas lorsqu'il transporte, pendant la durée spécifiée dans le Tableau S.2, un courant égal à deux fois la caractéristique assignée du dispositif de protection contre les surintensités du circuit de dérivation (voir S.4.4.4.2.200) et de 40 A au maximum, et

d) si aucun des trois échantillons du conducteur de liaison ne s'ouvre pendant un essai de court-circuit limité avec un courant tel que celui spécifié dans le Tableau S.3 lorsqu'il est mis en série avec un fusible comme cela est décrit dans l’alinéa suivant.

Tableau S.1 – Dimension du conducteur de liaison

Caractéristique assignée ou réglage maximal du dispositif automatique de protection contre les *surintensités* avant le *BDM/CDM/PDS* A	**Dimension minimale du conducteur de liaison**[a]			
	Fil en cuivre AWG (mm^2)		**Fil en aluminium AWG ou kcmil** (mm^2)	
15	14	(2,1)	12	(3,3)
20	12	(3,3)	10	(5,3)
30	10	(5,3)	8	(8,4)
40	10	(5,3)	8	(8,4)
60	10	(5,3)	8	(8,4)
100	8	(8,4)	6	(13,3)
200	6	(13,3)	4	(21,2)
300	4	(21,2)	2	(33,6)
400	3	(26,7)	1	(42,4)
500	2	(33,6)	1/0	(53,5)
600	1	(42,2)	2/0	(67,4)
800	1/0	(53,5)	3/0	(85,0)
1 000	2/0	(67,4)	4/0	(107,0)
1 200	3/0	(85,0)	250	(127,0)

[a] Ou section équivalente.

Tableau S.2 – Durée de circulation du courant pour l'essai du conducteur de liaison

Caractéristique assignée du dispositif de protection contre les *surintensités* A	**Durée minimale de circulation du courant** Min
30 ou moins	1
31 à 60	4
61 à 100	6

Tableau S.3 – Capacité d'essai de court-circuit du conducteur de liaison

Caractéristique assignée du contrôleur			
hp	(sortie en kW)	V	Capacité du circuit A
1/2	(0,373)	0 à 250	200
1/2	(0,373)	251 à 600	1 000
Entre 1/2 et 1	(0,374 à 0,746)	0 à 600	1 000
1 à 3	(0,747 à 2,24)	0 à 250	2 000
Entre 3 et 7-1/2	(2,25 à 5,59)	0 à 250	3 500
Entre 7-1/2 et 10	(5,60 à 7,46)	0 à 250	5 000
Entre 10 et 50	(7,47 à 37,3)	251 à 600	5 000
Entre 50 et 200	(37,4 à 149)	0 à 600	10 000
Supérieur à 200	(supérieur à 150)	0 à 600	[a]
[a] Voir le Tableau 36.			

Le facteur de puissance du circuit prévu pour l'essai exigé dans l'alinéa ci-dessus doit être de 0,9 à 1,0 et doit être limité au courant spécifié dans le Tableau S.3. La tension de court-circuit du circuit d'essai doit être comprise entre 100 % et 105 % de la tension spécifiée. Le circuit doit être connecté par un fusible non réarmable qui conduit deux fois son courant assigné pendant au moins 12 s. Les caractéristiques assignées du fusible doivent être celles du dispositif de protection contre les *surintensités* du circuit de dérivation auquel le *BDM/CDM/PDS* est destiné à être relié, et ne pas être inférieur à 20 A. Un essai doit être réalisé sur chacun des trois échantillons du conducteur de liaison.

S.4.4.4.3 *Conducteur de mise à la terre de protection*

S.4.4.4.3.1 Généralités

Ajout à 4.4.4.3.1:

Le *conducteur de mise à la terre de protection* doit être dimensionné comme cela est spécifié dans l'Article 250.122 et le Tableau 250.122 du National Electrical Code ANSI/NFPA 70.

Pour la couleur de la mise à la terre interne et du conducteur de liaison, voir 4.11.5.

S.4.4.4.3.2 Dispositifs de raccordement du conducteur *de mise à la terre de protection*

Ajout à 4.4.4.3.2:

Les *BDM/CDM/PDS portatifs* doivent être équipés d'un cordon d'alimentation avec un conducteur de mise à la terre. Le conducteur de mise à la terre doit être relié à la lame de mise à la terre d'une prise de branchement de mise à la terre et doit être relié au châssis ou à l'*enveloppe* du *BDM/CDM/PDS*. La surface de l'*isolation* sur le conducteur de mise à la terre doit être verte avec ou sans une ou plusieurs bandes jaunes.

Si aucun moyen de mise à la terre n'est prévu sur le *BDM/CDM/PDS* lors de sa livraison, le *BDM/CDM/PDS* doit être marqué selon 6.3.7.5.

S.4.4.4.3.3 *Courant de contact* en cas de défaillance du *conducteur de mise à la terre de protection*

Ajout à 4.4.4.3.3:

Aux États-Unis, l'*équipement enfichable de type B* est un *BDM/CDM/PDS enfichable* intégrant une fiche ou un connecteur conforme à l'UL 498. Un *équipement enfichable de type A* est un *BDM/CDM/PDS* intégrant une fiche ou un connecteur conforme à une autre norme appropriée relative aux fiches et aux connecteurs.

S.4.4.5 Mesures de *protection renforcée*

S.4.4.6 Mesures de protection

Ajout de paragraphes supplémentaires au 4.4.6:

S.4.4.6.200 Mise à la terre du transformateur de *circuit de commande*

Si le secondaire d'un transformateur de *circuit de commande* est destiné à alimenter un circuit externe, il doit être relié à la *mise à la terre de protection* dans l'un des cas suivants:

a) si la tension primaire du transformateur dépasse 150 V à la terre et que la tension secondaire est de 50 V au maximum;
b) si la tension secondaire est comprise entre 50 V et 1 000 V, et que le secondaire peut être relié à la *mise à la terre de protection* de sorte que la tension maximale à la terre des conducteurs non mis à la terre ne dépasse pas 150 V.

S.4.4.6.201 Transformateurs

S.4.4.6.201.1 Protection du transformateur de *circuit de commande*

Outre ce qui est indiqué dans l'alinéa suivant, un transformateur dont le secondaire alimente un circuit intégrant la bobine d'un contacteur de commande externe ou interne (pour un redémarrage à chaud, par exemple) doit être équipé d'une protection supplémentaire. La protection doit être un élément supplémentaire ou un fusible de type circuit de dérivation conforme à la série UL 248 ou à l'UL 489 respectivement et doit

a) pour le primaire:
   1) être prévue dans chaque conducteur non mis à la terre du primaire du transformateur et adaptée ou réglée selon le Tableau S.4; et soit;
   2) être prévue dans le primaire du transformateur et adaptée ou réglée au maximum à 6 fois le courant assigné du primaire du transformateur lorsque l'impédance du transformateur ne dépasse pas 6 % et que la protection thermique coordonnée contre les surcharges est prévue pour interrompre le circuit primaire; soit

3) être prévue dans le primaire du transformateur et adaptée ou réglée au maximum à 4 fois le courant assigné du primaire du transformateur lorsque l'impédance du transformateur est supérieure à 6 % et inférieure à 10 % et que la protection thermique coordonnée contre les surcharges est prévue pour interrompre le circuit primaire;

b) pour le primaire et le secondaire:

4) être prévue dans le primaire du transformateur et adaptée ou réglée à 250 % maximum du courant primaire assigné du transformateur et prévue dans le secondaire du transformateur et adaptée ou réglée à 125 % maximum du courant secondaire; ou

5) être prévue dans le primaire du transformateur et adaptée ou réglée à 250 % maximum du courant primaire assigné du transformateur et prévue dans le secondaire du transformateur et adaptée ou réglée selon la ligne 2 du Tableau S.4 lorsque le courant secondaire assigné du transformateur est d'au moins 2 A.

Il n'est pas exigé de prévoir une protection supplémentaire pour un transformateur lorsque l'une des conditions suivantes existe:

a) le secondaire du transformateur alimente un *circuit de commande* à puissance limitée de Classe 1 ou dans un *circuit de commande* à distance de Classe 3 ou alimente un circuit secondaire de Classe 2 (voir S.203.1.5), de tension/courant limité (voir S.203.1.6), d'énergie limitée (voir S.203.1.7) ou d'impédance de limitation (voir S.203.1.8);
b) le secondaire du transformateur est assigné à moins de 50 VA, est protégé par nature et fait partie intégrante du *BDM/CDM*;
c) la protection du circuit de dérivation assure la protection supplémentaire exigée; ou,
d) La protection supplémentaire est assurée par d'autres moyens satisfaisant aux exigences applicables du National Electrical Code, ANSI/NFPA 70.

Tableau S.4 – Caractéristique assignée minimale du dispositif de protection contre les *surintensités*

Caractéristique assignée de courant primaire A	Caractéristique assignée maximale du dispositif de protection contre les *surintensités* en pourcentage du courant assigné primaire du transformateur
Moins de 2	500
2 à moins de 9	167
9 ou plus	125 [a]

[a] Si 125 % du courant ne correspond à aucune caractéristique assignée normalisée du fusible ou du disjoncteur non réglable, la caractéristique assignée normalisée immédiatement supérieure doit être utilisée. Voir la Section 240-6 du National Electrical Code, ANSI/NFPA 70.

S.4.4.6.201.2 Combinaison de câblage du *circuit de commande*/transformateur

Pour un transformateur monophasé avec un seul secondaire à 2 fils, les exigences supplémentaires de protection du câblage et du transformateur du S.4.11.200.1 et du S.4.4.6.201.1 peuvent être satisfaites par les dispositifs de protection dans un conducteur primaire non mis à la terre. Les dispositifs de protection doivent

a) se trouver dans le primaire du transformateur,
b) présenter une caractéristique assignée maximale ou une limite de réglage calculée en utilisant la valeur appropriée du dispositif de protection issue du Tableau S.12 reposant sur l'AWG du câblage secondaire, puis en multipliant cette valeur par le rapport de tension secondaire/primaire du transformateur, et
c) présenter une caractéristique assignée réelle ou un réglage dans les limites maximales et également être conforme à S.4.4.6.201.2 a) et b).

S.4.4.6.201.3 Performances

Outre ce qui est indiqué dans l'alinéa suivant, un transformateur utilisé dans un *BDM/CDM/PDS* doit satisfaire à la norme appropriée en matière de transformateurs, sauf si la charge fait partie intégrante du *BDM/CDM/PDS*, auquel cas le transformateur doit satisfaire à l'essai de température (5.2.3.10) et à l'essai de tension en courant alternatif ou en courant continu (5.2.3.4).

Les transformateurs d'alternance et de courant construits d'une autre manière que celle exigée par la norme UL applicable en matière de transformateur satisfont aux exigences de l'alinéa ci-dessus lorsqu'ils résistent, sans claquage, à un potentiel de tenue en tension diélectrique selon l'essai de tension en courant alternatif ou en courant continu (5.2.3.4), appliqué entre les enroulements primaire et secondaire. Il s'agit par exemple de transformateurs dont la construction s'appuie sur un revêtement de fil électrique assurant l'isolation en lieu et place d'une bande entre enroulements.

S.4.4.7 *Isolation*

S.4.4.7.1 Facteurs d'influence

S.4.4.7.1.1 Généralités

Ajout à 4.4.7.1.1:

Les *bornes pour câblage externe* qui n'excluent pas la possibilité de brins dispersés doivent satisfaire aux exigences en matière de *distance d'isolement* et de *lignes de fuite* du S.200.1.

Pour une *enveloppe* sans ouverture de conduit ou ouverture défonçable, des *distances d'isolement* et *lignes de fuite* non inférieures à celles spécifiées en S.200.1 doivent être prévues entre les *parties actives* non isolées et une traversée de conduit installée dans un emplacement pendant l'installation. Un marquage permanent sur l'*enveloppe*, un modèle ou un schéma pleine échelle fourni avec le *BDM/CDM/PDS* est utilisable pour identifier ces emplacements. Pour mesurer la *distance d'isolement* et les *lignes de fuite*, il doit être pris pour hypothèse qu'une traversée ayant les dimensions spécifiées dans le Tableau S.5 est en place, avec un seul écrou de blocage installé sur l'extérieur de l'*enveloppe*.

Tableau S.5 – Dimensions des traversées

Dimension commerciale du conduit in	Dimensions de la traversée en (mm)			
	Diamètre total maximal		Hauteur	
1/2	1	(25,4)	3/8	(9,5)
3/4	1-15/64	(31,4)	27/64	(10,7)
1	1-19/32	(40,5)	33/64	(13,1)
1-1/4	1-15/16	(49,2)	9/16	(14,3)
1-1/2	2-13/64	(56,0)	19/32	(15,1)
2	2-45/64	(68,7)	5/8	(15,9)
2-1/2	3-7/32	(81,8)	3/4	(19,1)
3	3-7/8	(98,4)	13/16	(20,6)
3-1/2	4-7/16	(113)	15/16	(23,8)
4	4-31/32	(126)	1	(25,4)
5	6-7/32	(158)	1-3/16	(30,2)
6	7-7/32	(183)	1-1/4	(31,8)

Pour les joints isolants serrés, les *distances d'isolement* et les *lignes de fuite* doivent être mesurées à travers les fissures représentées à la Figure S.5 sauf si les joints isolants serrés satisfont aux exigences du S.200.1.

Les *distances d'isolement* et les *lignes de fuite* placées côté alimentation des dispositifs de protection de circuit de dérivation des *BDM/CDM/PDS* assignés à 600 V au maximum et destinés à être installés dans un circuit d'alimentation doivent être conformes au Tableau S.6.

Tableau S.6 – *BDM/CDM/PDS* destinés à être installés dans un circuit d'alimentation

Tension entre les parties concernées	***Distances d'isolement* et *lignes de fuite* minimales en pouces** (mm)							
	Entre les parties non isolées de polarité opposée côté alimentation				**Entre les parties non isolées côté alimentation et un métal inerte mis à la terre**			
	Lignes de fuite		***Distance d'isolement***		***Lignes de fuite***		***Distance d'isolement***	
0 à 125	3/4	(19,1)	1/2	(12,7)	1/2	(12,7)	1/2	(12,7)
126 à 250	1-1/4	(31,8)	3/4	(19,1)	1/2	(12,7)	1/2	(12,7)
251 à 600	2	(50,8)	1	(25,4)	1	(25,4)	1	(25,4)

S.4.4.7.1.2 *Tension de fonctionnement*

S.4.4.7.1.3 Degré de pollution

Ajout à 4.4.7.1.3:

Le système d'*isolation du moteur* doit satisfaire aux exigences de la série UL 1004.

Le degré de pollution 1 peut être obtenu par encapsulation ou scellement hermétique du produit. Les constructions classiques qui satisfont à cette exigence sont:

a) l'utilisation d'un revêtement conforme sur les cartes de circuit imprimé qui satisfait aux exigences de revêtement conforme de l'UL 746C Standard for Polymeric Materials – Electrical Equipment Evaluations;
b) l'utilisation d'un matériau d'empotage ou d'une encapsulation (l'époxy, par exemple);
c) l'utilisation d'un ruban en silicone d'une épaisseur d'au moins 1/32 in (0,8 mm);
d) l'utilisation d'un boîtier ou d'une enveloppe hermétiquement scellée pour éviter la pénétration d'une atmosphère extérieure par fusion (brasage tendre, brasage fort, soudage ou fusion du verre et du métal, par exemple).

Le degré de pollution 2 peut être obtenu en réduisant les possibilités de pollution conductrice et de condensation ou d'humidité élevée au niveau des *lignes de fuite*.

e) les constructions classiques qui réduisent la possibilité de pollution conductrice sont les suivantes
   1) l'utilisation d'une *enveloppe* non ventilée; ou
   2) l'utilisation d'une *enveloppe* ventilée si tous les orifices de ventilation sont équipés de filtres;

f) les constructions classiques qui réduisent les effets de la condensation ou de l'humidité élevée sont
   1) l'utilisation d'une *enveloppe* de ventilation;
   2) l'application continue de chaleur à l'aide de chauffages;
   3) l'application de chaleur par mise sous tension continue du *BDM/CDM/PDS*, avec des interruptions permettant d'éviter un refroidissement jusqu'au point de condensation; ou
   4) l'utilisation d'un revêtement (un masquage de soudure, par exemple) sur les traces de feuille de carte de circuit imprimé.

S.4.4.7.2 *Isolation* par rapport à l'environnement

S.4.4.7.2.1 Généralités

S.4.4.7.2.2 Surveillance du *SPD*

S.4.4.7.2.3 Circuits connectés directement au *réseau*

Ajout à 4.4.7.2.3:

Le *PDS* doit être évalué au moins comme une Catégorie de surtension III.

S.4.4.7.2.4 Circuits connectés à l'alimentation *non raccordée directement au réseau*

S.4.4.7.2.5 *Isolation* entre les circuits

Ajout à 4.4.7.2.5:

Dans la zone du *câblage externe*, des dispositions en matière de câblage des circuits de Classe 2 et de Classe 3 doivent satisfaire aux exigences de séparation des circuits de Classe 1 conformément à la Section 725 du National Electrical Code, ANSI/NFPA 70. Voir également S.203.1.1.

S.4.4.7.3 *Isolation fonctionnelle*

S.4.4.7.4 *Distance d'isolement*

S.4.4.7.5 *Lignes de fuite*

S.4.4.7.6 Revêtement ou empotage

Ajout à 4.4.7.6:

Les *distances d'isolement* et les *lignes de fuite* dont il est exigé qu'elles soient supérieures à 1/32 in (0,8 mm) peuvent être réduites à 1/32 in (0,8 mm) sur une carte de circuit imprimé lorsque les *distances d'isolement* et *lignes de fuite* de cette dernière sont

a) recouvertes d'une couche de caoutchouc de silicone d'au moins 1/32 in (0,8 mm) d'épaisseur, ou
b) encapsulés par un matériau époxy ou d'empotage, sans bulle d'air. Le caoutchouc de silicone et le matériau d'empotage, s'ils sont utilisés, doivent satisfaire à l'UL 94, à l'UL 746B, ou à l'UL 746C.

S.4.4.7.7 *Distance* d'isolement *et lignes* de *fuite d'une* carte de circuit *imprimé* et des composants assemblés sur une carte de circuit imprimé pour une *isolation fonctionnelle*

S.4.4.7.8 Isolation solide

S.4.4.7.8.1 Généralités

S.4.4.7.8.2 Exigences du matériau

Ajout à 4.4.7.8.2:

À l’exception de ce qui est indiqué dans les alinéas suivants, un matériau isolant doit

a) satisfaire à 4.4.7.8.2, et

b) présenter une épaisseur d'au moins 0,028 in (0,71 mm).

Ces deux exigences sont indépendantes l'une de l'autre. Par exemple, même si un matériau satisfait à 4.4.7.8.2 avec une épaisseur inférieure à la limite de 0,028 in (0,71 mm), il est toujours exigé de le fournir à une épaisseur au moins égale à cette limite de 0,028 in (0,71 mm) ou à l'épaisseur spécifiée dans les deux alinéas suivants.

Un matériau qui satisfait à 4.4.7.8.2 et ne satisfait pas à la limite d'épaisseur indiquée en b) peut par ailleurs être soumis à l'essai de tenue en tension diélectrique de 5 000 V en courant alternatif selon les exigences de barrière interne de l'UL 746C.

L'épaisseur d'un matériau qui satisfait à 4.4.7.8.2 et qui est de plus utilisé à pas moins de la moitié des *distances d’isolement* dans l'air et des *lignes de fuite* exigées, peut être inférieure à 0,028 in (0,71 mm) et doit être d'au moins 0,013 in (0,33 mm). Ce matériau doit

a) présenter la résistance mécanique exigée lorsqu'il est exposé ou soumis à des dommages mécaniques,

b) rester en place, et

c) être placé, c'est-à-dire ne pas être compromis par le fonctionnement du *BDM/CDM/PDS* en service.

Aucune autre évaluation n'est exigée lorsque les matériaux génériques du Tableau S.7 sont utilisés à une distance plus importante que celles du Tableau 12, dans les limites de l'épaisseur minimale du Tableau S.7, et lorsque la température mesurée lors de l'essai d'échauffement ne dépasse pas les limites de température du Tableau S.7.

Tableau S.7 – *Matériaux génériques pour les barrières*

Matériau générique	Épaisseur minimale mm	Température maximale °C
Papier d'aramide	0,25	105
Batiste	0,71	105
Papier de classe électrique	0,71	105
Époxy	0,71	105
Mica	0,71	105
Mylar (PET)	0,71	105
RTV	0,71	105
Silicone	0,71	105
Tissu traité	0,71	105
Fibre vulcanisée	0,71	105

Ajout d'un paragraphe supplémentaire à 4.4.7:

S.4.4.7.200 Dispositifs d'isolement

Les isolateurs optiques qui assurent l'isolation entre les circuits primaire et secondaire doivent être construits selon l'UL 1577, à l'exception de ce qui est indiqué dans l'alinéa suivant. La tension d'isolation assignée de l'isolateur optique doit être au moins égale à la tension d'essai de caractéristique assignée de tenue en tension diélectrique minimale exigée par 5.2.3.4 (Essai de tension en courant alternatif ou en courant continu). D'autre part, un isolateur optique construit selon les exigences de l'UL 1577, et adapté à un potentiel diélectrique inférieur à celui exigé par l'essai de tension en courant alternatif ou en courant continu, 5.2.3.4, satisfait au présent article si l'épaisseur de l'*isolation* interne est telle qu'il satisfait également à l'épaisseur minimale de 0,71 mm.

Il n'est pas exigé qu'un isolateur optique satisfasse aux exigences de l'UL 1577 Standard for Optical Isolators si le matériau et l'épaisseur de l'*isolation* interne sont tels qu'il satisfait à S.4.4.7.8.2.

Les dispositifs semiconducteurs de puissance qui assurent l'isolation à la terre doivent être construits selon l'UL 1557, à l'exception de ce qui est indiqué dans l'alinéa suivant. Les essais de tenue en tension diélectrique exigés par l'UL 1557 doivent être réalisés à un potentiel diélectrique selon l'essai de tension en courant alternatif ou en courant continu (5.2.3.4). D'autre part, il n'est pas exigé qu'un semiconducteur de puissance construit selon l'UL 1557 et adapté à un potentiel diélectrique inférieur à celui exigé par l'essai de tension en courant alternatif ou en courant continu (5.2.3.4) satisfasse au présent alinéa si l'épaisseur de l'*isolation* interne sont a une épaisseur minimale de 0,71 mm.

Il n'est pas exigé qu'un semiconducteur de puissance satisfasse aux exigences de l'UL 1557 si le matériau et l'épaisseur de l'*isolation* interne sont tels qu'il satisfait à l'épaisseur minimale de 0,71 mm.

Ajout de paragraphes supplémentaires à 4.4:

S.4.4.200 Moteurs de ventilateur

Outre les moteurs de ventilateur se trouvant dans un circuit secondaire relevant de la Classe 2 (voir S.203.1.5), de courant/tension limité (voir S.203.1.6) ou d'impédance de limitation (voir S.203.1.7), chaque moteur de ventilateur doit être équipé

a) d'une protection contre le rotor bloqué selon l'alinéa suivant, et
b) d'une *enveloppe* conforme à celles du S.4.12.

La protection contre le rotor bloqué exigée par l'élément a) de l'alinéa ci-dessus doit

c) satisfaire aux exigences de protection thermique de l'UL 2111, ou,
d) satisfaire aux exigences de protection d'impédance de l'UL 2111, ou,
e) utiliser d'autres moyens de protection dont l'essai indique qu'ils sont équivalents à la protection spécifiée en c).

Concernant l'élément e) ci-dessus, l'utilisation d'une fusion pour limiter la température du rotor bloqué des enroulements du moteur de ventilateur selon les exigences de protection thermique de l'UL 2111 est un exemple d'autre moyen de protection. Dans cet exemple, la fusion doit être un circuit de dérivation ou des types supplémentaires conformément à la série UL 248.

S.4.4.201 Porte-fusibles

Outre ce qui est indiqué dans les deux alinéas suivants, un *BDM/CDM* intégrant un sectionneur et un porte-fusible doit être construit de sorte que lorsque les contacts du commutateur sont ouverts, le fusible puisse être remplacé sans toucher les parties sous tension.

Il n'est pas exigé qu'une disposition de fusible de commande/circuit satisfasse à cette exigence lorsque le fusible et la charge de commande/circuit (autre qu'une charge de commande/circuit fixe, telle qu'une lampe témoin, par exemple) se trouvent dans la même *enveloppe*.

Cette exigence ne s'applique pas aux fusibles inaccessibles et ne concerne pas le renouvellement. Les fusibles sont considérés comme étant inaccessibles lorsqu'il est exigé de détruire ou d'endommager l'*enveloppe* ou certaines parties de l'assemblage pour toucher les *parties actives*.

S.4.5 Protection contre les dangers dus à l'énergie électrique

S.4.6 Protection contre les dangers d'incendie et thermiques

S.4.6.1 Généralités

S.4.6.2 Circuits et *composants* représentant un danger d'incendie

Ajout à 4.6.2:

Un contacteur dans un circuit de puissance doit permettre de contrôler la charge connectée, y compris la fermeture, le transport et la coupure du courant de surcharge qui peut être délivré par le *BDM/CDM/PDS*. Un contacteur aux caractéristiques assignées inférieures peut être utilisé lorsqu'il est verrouillé ou séquencé de sorte que, dans des conditions normales de fonctionnement, il ne ferme ni ne coupe le courant de charge et qu'il satisfasse aux exigences du S.5.2.4.200.

S.4.6.3 Sélection des *composants* pour atténuer le risque d'un danger d'incendie

S.4.6.4 Protection contre le feu *fournie* par les *enveloppes*

Remplacement du 4.6.4:

Voir S.4.12 pour les exigences relatives aux enveloppes aux États-Unis.

Ajout d'un paragraphe supplémentaire à 4.6:

S.4.6.200 *BDM/CDM* utilisé dans les espaces de traitement de l'air (chambres de répartition d'air)

Les *BDM/CDM* destinés à être utilisés dans des conduits de traitement de l'air et les chambres de répartition d'air doivent être de type sous enveloppe et doivent satisfaire à toutes les autres exigences applicables du présent document.

Les *BDM/CDM* avec des *enveloppes* qui sont en tout ou partie non métalliques et qui sont destinés à être installés dans des espaces de traitement de l'air doivent en outre satisfaire aux exigences de l'UL 2043.

Les exigences de l'alinéa ci-dessus ne s'appliquent pas:

a) aux filtres à air, aux courroies de *BDM/CDM*, à l'*isolation* des fils, à la peinture utilisée pour la protection contre la corrosion ou à la tuyauterie en matériau équivalent à l'un des types d'*isolation* des fils admis dans le présent document;
b) les joints d'étanchéité assurant l'étanchéité à l'air ou à l'eau entre les parties métalliques;
c) diverses petites parties telles que les traversées de conduite de frigorigène ou les traversées isolantes, les montages élastiques ou antivibratoires, les fils métalliques d'attache, les pinces, les étiquettes ou les attaches de conduite de récupération des fuites dont la surface totale exposée ne dépasse pas 25 pouces carrés (161,29 cm^2);
d) un adhésif qui, lorsqu'il est soumis à l'essai associé à un matériau isolant particulier, satisfait à cette exigence.

Les surfaces d'*enveloppes* métalliques, y compris celles qui sont ventilées, sont adaptées à une utilisation dans des conduits de traitement de l'air et les chambres de répartition d'air sans examen supplémentaire.

S.4.7 Protection contre les dangers mécaniques

S.4.7.1 Généralités

S.4.7.2 Vitesse de torsion critique

S.4.7.3 Analyse du couple transitoire

S.4.7.4 Exigences spécifiques pour le BDM/*CDM/PDS refroidi* par liquide

S.4.7.4.1 Généralités

S.4.7.4.2 Liquide de refroidissement

Ajout à 4.7.4.2:

Le liquide de refroidissement spécifié (voir 6.2) doit être adapté à une *température ambiante* prévue comprise entre 0 °C et 40 °C (32 F et 104 °F), sauf s'il est prévu et marqué pour une plage de températures différente.

S.4.7.4.3 Exigences de la conception

S.4.7.4.3.1 Généralités

S.4.7.4.3.2 Résistance à la corrosion

S.4.7.4.3.3 Tuyauterie, durites et joints d'étanchéité

Ajout à 4.7.4.3.3:

La tuyauterie utilisée pour relier les composants contenant le réfrigérant doit satisfaire aux exigences d'épaisseur de paroi minimale indiquées dans le Tableau S.8 et aux exigences d'essai de pression hydrostatique du 5.2.7.

Tableau S.8 – Épaisseur de paroi minimale de la tuyauterie

Diamètre extérieur		Épaisseur minimale de paroi[a] in (mm)					
		Cuivre				Acier	
in	(mm)	Protégée		Non protégée			
3/16	(4,76)	0,024 5	(0,62)	0,026 5	(0,67)	0,025	(0,64)
1/4	(6,35)	0,024 5	(0,62)	0,026 5	(0,67)	0,025	(0,64)
5/16	(7,94)	0,024 5	(0,62)	0,028 5	(0,72)	0,025	(0,64)
3/8	(9,53)	0,024 5	(0,62)	0,028 5	(0,72)	0,025	(0,64)
1/2	(12,70)	0,024 5	(0,62)	0,028 5	(0,72)	0,025	(0,64)
5/8	(15,88)	0,031 5	(0,80)	0,031 5	(0,80)	0,032	(0,81)
3/4	(19,05)	0,031 5	(0,80)	0.038 5	(0,98)	0,032	(0,81)
7/8	(22,23)	0,041 0	(1,04)	0,041 0	(1,04)	0,046	(1,17)
1	(25,40)	0,046 0	(1,17)	0,046 0	(1,17)	0,046	(1,17)
1-1/8	(28,58)	0,046 0	(1,17)	0,046 0	(1,17)	0,046	(1,17)
1-1/4	(31,75)	0,050 5	(1,28)	0,050 5	(1,28)	0,046	(1,17)
1-3/8	(34,93)	0,050 5	(1,28)	0,050 5	(1,28)	0,046	(1,17)
1-1/2	(38,10)	0,055 5	(1,41)	0,055 5	(1,41)	0,062	(1,58)
1-5/8	(41,3)	0,055 5	(1,410)	0,055 5	(1,410)	-	-
2-1/8	(54,0)	0,064 0	(1,626)	0,064 0	(1,626)	-	-
2-5/8	(66,7)	0,074 0	(1,880)	0,074 0	(1,880)	-	-

NOTE "Protégée" implique que la tuyauterie est protégée par l'armoire ou l'assemblage, de manière à éviter les dommages imprévus provoqués par des objets (des outils qui tombent sur la tuyauterie ou qui la percutent pendant la manipulation et après l'installation de l'unité, par exemple). Cette protection peut se présenter sous la forme de cloisons, de canaux, de brides, de métal perforé ou de moyens équivalents. Si une armoire est utilisée pour l'installation prévue d'une unité, la tuyauterie est considérée comme étant protégée. La tuyauterie ne faisant pas l'objet de ce type de protection est considérée comme n'étant pas protégée.

[a] L'épaisseur de paroi nominale de la tuyauterie doit être supérieure à l'épaisseur indiquée pour maintenir l'épaisseur de paroi minimale.

S.4.7.4.3.4 Disposition pour la condensation

S.4.7.4.3.5 Conductivité du liquide de refroidissement

S.4.7.4.3.6 Fuite du liquide de refroidissement

Ajout à 4.7.4.3.6:

Si un limiteur de pression est fourni, il doit satisfaire à l'essai de pression hydrostatique (voir 5.2.7). Le liquide de refroidissement libéré après le fonctionnement d'un limiteur de pression ne doit pas s'écouler dans le compartiment électrique.

Ajout d'un paragraphe supplémentaire à 4.7:

S.4.7.200 Protection contre l'inversion de phase

Un *BDM/CDM/PDS* équipé d'une protection contre l'inversion de phase doit interrompre l'alimentation et maintenir l'interruption dans tout le circuit du moteur.

S.4.8 *BDM/CDM/PDS* à plusieurs sources d'alimentation

S.4.9 Protection contre les contraintes environnementales

Ajout à 4.9:

Il n'est pas exigé de déclarer la résistance à l'humidité, aux vibrations et aux ultraviolets. La *température ambiante*, si applicable, est uniquement exigée si une autre caractéristique assignée de *température de l'air ambiant environnant* est exigée. Le degré de pollution est uniquement exigé si le *BDM/CDM/PDS* est uniquement adapté à une utilisation dans un environnement de degré de pollution 2.

S.4.10 Protection contre les dangers de bruit acoustique excessif

S.4.11 Câblage et raccordements

S.4.11.1 Généralités

S.4.11.2 *Isolation* des conducteurs

Ajout à 4.11.2:

Le câblage faisant l'objet de courbure pendant le service (celui d'une partie fixée à demeure ou celui monté sur une *porte* battante ou une autre partie mobile, par exemple) doit être équipé d'une *isolation* d'au moins 1/32 in (0,8 mm) d'épaisseur. Le câblage doit être un cordon souple ou doit satisfaire à l'un ou l'autre des points suivants.

a) Un câblage autre qu'un cordon souple peut être utilisé s'il est accompagné d'une *isolation* supplémentaire en tous ses points de courbure. L'*isolation* supplémentaire doit être un manchon isolant, un tuyau ou un enrobage au moins égal à deux couches de ruban isolant. L'*isolation* doit être constituée de matériaux prévus pour la température et la tension concernées.
b) Un câblage autre qu'un cordon souple peut être utilisé sans *isolation* supplémentaire lorsqu'il n'apparaît pas évident que le câblage est endommagé, et que le câblage résiste à l'essai de tension en courant alternatif ou en courant continu (5.2.3.4) appliqué entre les conducteurs et entre les conducteurs et la terre, après que le câblage a été monté comme prévu et soumis à l'essai en ouvrant la *porte* ou une autre partie mobile dans toute la mesure du possible, puis en la ramenant dans sa position initiale pendant 500 cycles de fonctionnement (contraintes de sorte que la chaîne reste en place).

S.4.11.3 Fil multibrin

Ajout à 4.11.3:

Il n'est pas exigé que les *bornes pour câblage externe* excluent la possibilité de brins dispersés si la *distance d'isolement* et les *lignes de fuite* des *bornes pour câblage externe* satisfont à S.200.1.

Les connecteurs de borne dont la pression est appliquée par une machine ou un outil, les cosses à souder, les œillets sertis ou le soudage de tous les brins du câble ensemble sont autant de moyens de câblage interne reliés à une vis de serrage empêchant les brins de se desserrer des parties en contact, comme cela est indiqué dans le second alinéa du 4.11.3.

S.4.11.4 Cheminement et serrage

S.4.11.5 Identification des conducteurs et des bornes du *réseau* et de l'alimentation *non raccordée directement au réseau*

Remplacement du 4.11.5:

Les conducteurs de mise à la terre et de liaison isolés inférieurs à 4 AWG doivent être identifiés par la couleur verte avec ou sans bandes jaunes sur l'ensemble du produit. Les conducteurs isolés dimensionnés 4 AWG ou plus doivent être identifiés de cette manière ou doivent l'être en chaque point de terminaison par un marquage vert (une bande verte enroulée autour du conducteur, par exemple). Aucun autre fil ne doit être identifié de cette manière. Les exigences ne s'appliquent pas à un conducteur vert ou vert/jaune fourni dans un faisceau électrique, un câble à rubans ou un câblage préfabriqué similaire, qui n'est pas susceptible d'être confondu avec un conducteur de mise à la terre.

S.4.11.6 Épissures et raccordements

Ajout à 4.11.6:

Une épissure doit être prévue avec l'*isolation*, équivalente à celle des fils concernés.

L'*isolation* doit être constituée de matériaux prévus pour la température et la tension concernées. Pour déterminer à quel moment l'*isolation* d'une épissure composée de tissu enduit, de thermoplastique ou d'autres types de tuyauteries, les propriétés électriques et mécaniques, y compris la capacité de tenue en tension diélectrique, la résistance à la chaleur et la résistance à l'humidité, doivent être évaluées. Pour les exigences de l'*isolation* supplémentaire, l'alinéa suivant s'applique. La bande thermoplastique ne doit pas être enroulée sur un bord aiguisé ou un raccordement.

L'*isolation* supplémentaire, si elle est utilisée, doit être un manchon isolant, un tuyau ou un enrobage au moins égal à deux couches de ruban isolant. L'*isolation* doit être constituée de matériaux prévus pour la température et la tension concernées.

S.4.11.7 Connexions accessibles

S.4.11.8 Interconnexions entre les parties d'un *PDS*

S.4.11.9 Raccordement de l'alimentation *pour les BDM/CDM/PDS connectés en permanence*

Remplacement du 4.11.9:

Le *BDM/CDM/PDS* doit être construit de sorte que l'*installation* puisse satisfaire aux exigences de l'Article 310, du Tableau 310-16 ou du Tableau 310-17,selon le cas, du National Electrical Code, ANSI/NFPA 70.

Les *BDM/CDM/PDS* destinés à être *connectés en permanence* à l'alimentation doivent comporter des moyens de raccordement pour l'un des *systèmes* de câblage applicables conformément au National Electrical Code, ANSI/NFPA 70, sauf s'il est prévu de le perforer ou de le poinçonner sur le terrain pour installer un *système* de câblage et s'il est accompagné des instructions d'installation appropriées.

Un trou taraudé dans une *enveloppe* en métal coulé pour la fixation de conduits rigides filetés doit être prévu avec

a) une traversée intégrale comportant un orifice d'entrée lisse et arrondi dont le diamètre est identique au diamètre interne d'une traversée normalisée afin d'assurer une protection des conducteurs équivalente à celle fournie par ce type de traversée, ou doit être placé de manière à pouvoir la fixer à l'extrémité du conduit, et

b) au moins trois filets complets si le taraudage est réalisé tout le long de la paroi d'une *enveloppe* ou avec des filets complets d'au moins 3-1/2 dans le cadre d'une utilisation avec une traversée intégrale.

Par hypothèse, un *BDM/CDM/PDS* présentant un courant nominal ou une valeur assignée de cheval-vapeur avec un courant de moteur à pleine charge comme cela est spécifié dans le Tableau S.29 ou à l'Article S.204 est destiné à être relié avec un fil de la dimension déterminée selon le Tableau 310-16 du National Electrical Code, ANSI/NFPA 70. Sauf si elle est marquée selon 6.3.7.4.2 c) pour une utilisation uniquement avec un fil assigné à 75 °C (167 °F), la dimension doit être fondée sur un fil assigné pour une température de 60 °C (140 °F) pour les *BDM/CDM/PDS* assignés à 100 A au maximum, et sur un fil assigné à 75 °C pour les *BDM/CDM/PDS* assignés à plus de 100 A. Le type d'*isolation* n'est pas spécifié.

S.4.11.10 Raccordement de l'alimentation des *BDM/CDM/PDS* enfichables

S.4.11.10.1 Exigences relatives aux cordons (cordons *réseau,* par exemple)

Remplacement du 4.11.10.1:

Un *BDM/CDM* destiné à être relié à l'alimentation par un cordon doit être équipé d'un cordon souple pour service intense ou service léger (Type S, SJ ou équivalent, par exemple) dont la longueur, la dimension et le type sont évalués en fonction des conditions d'utilisation, se terminant par une prise de branchement avec mise à la terre et adapté à la température et la tension prévues.

Le *BDM/CDM/PDS* peut être relié à l'alimentation avec un cordon lorsque le *BDM/CDM/PDS* est

a) portatif,

b) posé librement ou stationnaire (non *connecté en permanence* au câblage du bâtiment), ou

c) un dispositif destiné à assurer une fonction de signalisation.

Le courant permanent admissible du cordon, comme cela est spécifié dans le Tableau S.9 ne doit pas être inférieur au courant permanent admissible exigé pour le *BDM/CDM/PDS* en S.4.11.11.2.

Tableau S.9 – Courant permanent admissible du cordon souple

Dimension du conducteur, AWG	Nombre de conducteurs	
	2	**3** [a]
18	10	7
16	13	10
14	18	15
12	25	20
10	30	25
8	40	35
6	55	45
4	70	60
2	95	80

[a] Si plus de trois conducteurs porteurs de courant sont fournis, le courant permanent admissible de chacun d'eux doit être: égal à 80 % de ces valeurs pour 4 à 6 conducteurs, à 70 % de ces valeurs pour 7 à 9 conducteurs, à 50 % de ces valeurs pour 10 à 20 conducteurs, à 45 % de ces valeurs pour 21 à 30 conducteurs, à 40 % de ces valeurs pour 31 à 40 conducteurs et à 35 % de ces valeurs pour 41 conducteurs ou plus.

Les *BDM/CDM/PDS* reliés par cordon et équipés d'une prise de branchement normalisée dont la valeur assignée en ampère dépasse le courant permanent admissible du cordon d'alimentation doivent être équipés d'un dispositif de protection contre les *surintensités* complet adapté au maximum au courant permanent admissible des conducteurs. Les *BDM/CDM/PDS* reliés par un cordon et équipés d'un connecteur multibroche ou sans prise de branchement ou connecteur doivent être

d) équipés d'un dispositif de protection contre les *surintensités* complet dont la valeur assignée ne dépasse pas le courant permanent admissible, ou
e) marqués selon S.6.3.9.6.5 pour indiquer les caractéristiques assignées du dispositif de protection contre les *surintensités* qui doit être installé sur site.

Un support d'attache doit être prévu sur l'alimentation ou les cordons multicâbles de signal. Le support d'attache doit être soumis à l'essai selon S.5.2.2.200.

Au point de passage du cordon dans la paroi de l'*enveloppe*, une protection doit être prévue pour éviter l'abrasion du cordon.

Si un nœud sert de support d'attache dans un cordon souple fixé, toute surface avec laquelle le nœud est en contact ne doit présenter aucun bord aiguisé, projection, bavure, ébarbure et autres irrégularités similaires qui abrasent l'*isolation* sur les conducteurs.

Des moyens doivent être prévus pour éviter que le cordon d'alimentation ne soit poussé dans l'*enveloppe* du *BDM/CDM/PDS* à travers l'orifice d'entrée du cordon lorsque ce type de situation

f) expose le cordon d'alimentation à des dommages mécaniques,
g) expose le cordon d'alimentation à une température supérieure à celle pour lequel il est prévu,
h) réduit les *distances d'isolement* et *lignes de fuite* (par rapport à un serre-câble métallique, par exemple) sous les valeurs exigées minimales, ou
i) endommage les connexions ou *composants* internes.

Pour déterminer la conformité, le cordon d'alimentation doit être soumis à l'essai selon S.5.2.2.200.2, essai de contrainte de refoulement.

Un cordon d'alimentation ou de connexion et de signalisation utilisé sur un *BDM/CDM/PDS* équipé

j) d'une *enveloppe* de type 3, 3R, 3S, 4, 4X, 6 ou 6P, doit être évalué pour une utilisation extérieure,

k) d'une *enveloppe* de type 6 ou 6P, doit être résistant à l'eau, et

l) d'une enveloppe de type 12, 12K ou 13, doit être résistant à l'huile (SO, SJO ou STO, par exemple).

Pour un dispositif destiné à assurer une fonction de signalisation, une prise de branchement n'est pas exigée.

Un fil destiné à être épissé sur site par rapport à un conducteur de circuit ne doit pas être inférieur à 18 AWG (0,82 mm^2) et l'épaisseur de l'*isolation* (en caoutchouc ou en thermoplastique) ne doit pas être inférieure à 1/32 in (0,8 mm).

S.4.11.11 Bornes

S.4.11.11.1 Exigences de construction

Ajout à 4.11.11.1:

Les bornes doivent satisfaire à l'UL 310, à l'UL 486A-486B, à l'UL 486E ou à l'UL 1059, selon le cas. Les bornes amenées à être câblées sur le terrain doivent être adaptées pour le câblage externe.

Il n'est pas exigé de fournir un connecteur de borne à pression, y compris celle dont la pression est appliquée par un outil, pour assurer la connexion sur site à l'alimentation ou à la charge en ce qui concerne les *BDM/CDM/PDS* dont le câblage externe est supérieur à 10 AWG (5,3 mm^2) si la construction satisfait aux conditions suivantes.

a) Les connecteurs de borne des *composants* sont disponibles auprès du fabricant du *BDM/CDM/PDS*, et un ou plusieurs connecteurs sont spécifiés pour l'installation sur site sur le *BDM/CDM/PDS*.

b) Un dispositif de fixation (un goujon, un écrou, un boulon, un ressort ou une rondelle plate ou un dispositif équivalent, par exemple) exigé pour l'installation

    1) fait partie intégrante de l'ensemble de bornes du *composant*, ou

    2) est monté ou emballé séparément du *BDM/CDM/PDS*.

c) L'installation de l'ensemble de bornes n'implique pas le desserrage ou le démontage d'une autre partie que le *capot* ou d'une autre partie donnant accès aux bornes. Les moyens de fixation des connecteurs de borne doivent être accessibles pour le serrage avant et après l'installation du conducteur.

d) Si la fixation du connecteur à pression fourni dans un ensemble de bornes du *composant* exige d'utiliser un outil spécial, des instructions d'utilisation de l'outil doivent accompagner l'ensemble de *composants* ou le *BDM/CDM/PDS*.

e) L'installation d'un connecteur de borne à pression de la manière prévue doit permettre d'obtenir un produit satisfaisant aux exigences du présent document.

f) Le *BDM/CDM/PDS* est marqué selon 6.3.7.4.2 d).

Une borne dont le câblage externe est supérieur à 10 AWG (5,3 mm^2) doit être connectée par une cosse à souder ou un serre-fil à pression. Une borne qui doit faire l'objet d'un raccordement maximal de 10 AWG (5,3 mm^2) doit être composée d'un étrier ou d'une vis de serrage avec une plaque à bornes à cosses retournées (ou un équivalent) afin de maintenir le câble en position ou doit être composée d'une cosse à souder ou d'un serre-fil à pression.

Une vis de serrage de connexions pour câblage externe de conducteurs de section supérieure à 14 AWG (2,1 mm^2) doit être de type N° 8 au moins.

Une vis de serrage destinée uniquement au câblage externe de conducteurs de section 14 AWG (2,1 mm^2) ou inférieur doit être de type N° 6 au moins.

Une plaque à bornes taraudée pour recevoir une vis de serrage doit être en métal d'au moins 0,030 in (0,76 mm) d'épaisseur pour une section de 14 AWG (2,1 mm^2) ou plus petite et d'au moins 0,050 in (1,27 mm) d'épaisseur pour un câble de section supérieure à 14 AWG (2,1 mm^2). La plaque doit comporter au moins deux filets complets, sauf si moins de filets permettent d'assurer une connexion sécurisée dans laquelle les filets ne s'ébavurent pas sous l'application d'un couple de serrage de 20 lb·in (2,3 Nm).

Le métal d'une plaque à bornes formée à partir de matières premières et dont l'épaisseur est celle exigée ci-dessus peut être extrudé au niveau du trou taraudé pour la vis de serrage afin de fournir deux filets complets.

Une vis de serrage doit rentrer dans le métal.

Une *borne pour câblage externe* en aluminium ou destinée au raccordement d'un fil en aluminium doit être AL7CU ou AL9CU.

S.4.11.11.2 Capacité de raccordement des bornes

Remplacement du 4.11.11.2, à l'exception du premier alinéa, qui s'applique:

Chacune des bornes du *BDM/CDM* doit être équipée de bornes de câblage ou de broches de raccordement assurant la connexion des connecteurs dont le courant permanent admissible est le suivant.

a) Pour les bornes d'alimentation, au moins 125 % du courant d'alimentation assigné maximal et au moins de 125 % du courant de moteur à pleine charge.
b) Pour les bornes de charge du moteur, au moins 125 % du courant de sortie marqué maximal et au moins 125 % du courant de moteur à pleine charge spécifiés dans le Tableau S.29 ou dans le Tableau S.30 pour les caractéristiques assignées de puissance de sortie en cheval-vapeur.
c) Pour les bornes d'un circuit de bus en courant continu destiné à alimenter au moins un onduleur, au moins 125 % du courant marqué maximal de ces bornes.
d) Pour les bornes de puissance non traitées en a), b), c) ou e), au moins 100 % du courant marqué maximal de ces bornes.
e) Sauf si cela est marqué conformément à S.6.3.7.4.1, pour les *BDM/CDM/PDS* contrôlant un moteur en courant continu destiné à fonctionner à partir d'une alimentation monophasée redressée:
    1) 190 % du courant à pleine charge lorsqu'un redresseur demi-onde est utilisé;
    2) 150% du courant à pleine charge lorsqu'un redresseur d'onde complète est utilisé.

Si les conducteurs pour câblage externe sont supérieurs à 10 AWG (5,3 mm^2), les *bornes pour câblage externe* ou les broches de raccordement peuvent être omises conformément à S.4.11.11.1.

La dimension du conducteur doit être déterminée à partir de la colonne 60 °C ou 75 °C du Tableau S.10 en fonction de la valeur calculée comme ci-dessus.

Sauf marquage contraire, utiliser un câble de 60 °C pour 100 A et moins et de 75 °C au-dessus de 100 A.

Les conducteurs en parallèle ne doivent pas être inférieurs à 1/0 AWG.

Si une *borne pour câblage externe* est en mesure de recevoir le conducteur à la dimension supérieure qui suit celui exigé en S.4.11.11.2, la borne doit satisfaire aux exigences de sécurité et de rupture correspondant à cette dimension de conducteur, sauf si un marquage du *BDM/CDM/PDS* limite son utilisation à la seule dimension de conducteur plus petite conformément à S.6.3.7.4.1.

Tableau S.10 – Courants d'alimentation assignés des conducteurs isolés

Dimension de fil AWG (mm^2)		**60 °C (140 °F)**		**75 °C (167 °F)**	
		Cuivre	**Aluminium**	**Cuivre**	**Aluminium**
24	(0,2)	2	-	-	-
22	(0,3)	3	-	-	-
20	(0,5)	5	-	-	-
18	(0,8)	7	-	-	-
16	(1,3)	10	-	-	-
14	(2,1)	15	-	15	-
12	(3,3)	20	15	20	15
10	(5,3)	30	25	30	25
8	(8,4)	40	30	50	40
6	(13,3)	55	40	65	50
4	(21,2)	70	55	85	65
3	(26,7)	85	65	100	75
2	(33,6)	95	75	115	90
1	(42,4)	110	85	130	100
1/0	(53,5)	-	-	150	120
2/0	(67,4)	-	-	175	135
3/0	(85,0)	-	-	200	155
4/0	(107,2)	-	-	230	180
-	-	-	-	-	-
kcmil	-	-	-	-	-
250	(127)	-	-	255	205
300	(152)	-	-	285	230
350	(177)	-	-	310	250
400	(203)	-	-	335	270
500	(253)	-	-	380	310
600	(304)	-	-	420	340
700	(355)	-	-	460	375
750	(380)	-	-	475	385
800	(405)	-	-	490	395
900	(456)	-	-	520	425
1 000	(506)	-	-	545	445
1 250	(633)	-	-	590	485
1 500	(760)	-	-	625	520
1 750	(887)	-	-	650	545
2 000	(1 013)	-	-	665	560

Ces valeurs de courant permanent admissible s'appliquent uniquement si pas plus de trois conducteurs doivent être installés sur site dans le conduit. Si au moins quatre conducteurs, autres qu'un conducteur de neutre transportant le courant différentiel, doivent être installés dans un conduit (comme cela est le cas compte tenu du nombre d'entrées de conduit que comporte l'équipement extérieur, du nombre de câbles exigés dans certains systèmes polyphasés ou pour d'autres raisons), le courant permanent admissible de chaque conducteur doit être égal à 80 % de ces valeurs entre 4 et 6 conducteurs, à 70 % de ces valeurs entre 7 et 24 conducteurs, à 60 % de ces valeurs entre 25 et 42 conducteurs et à 50 % de ces valeurs pour au moins 43 conducteurs.

NOTE 1 Pour plusieurs conducteurs de même dimension (1/0 AWG au moins) au niveau d'une borne, le courant permanent admissible est égal à la valeur du Tableau S.10 de ce conducteur multipliée par le nombre de conducteurs que la borne reçoit.

Ajout d'un paragraphe supplémentaire à 4.11.11.2:

S.4.11.11.2.200 Bornes de *circuit de commande*

Les bornes du circuit de commande, du circuit de signalisation ou du circuit de détection doivent accepter 14 AWG (2,1 mm^2) au moins, sauf si le marquage (sur le produit ou dans les instructions d'installation) indique un raccordement avec des connecteurs de dimension(s) 18 AWG (0,82 mm^2) et 16 AWG (1,3 mm^2).

S.4.11.11.3 Raccordement à des conducteurs externes

S.4.11.11.4 Espace de courbure des câbles de 10 mm2

Remplacement du 4.11.11.4, y compris son titre:

S.4.11.11.4 Espace de courbure des câbles de 8 AWG (8,4 mm^2) et plus

L'espace entre l'extrémité de la cosse à souder ou du serre-fil à pression pour le raccordement du câble installé sur site et la paroi de l'*enveloppe* vers laquelle le câble est dirigé à la sortie de la cosse ou du connecteur doit être égal à au moins la valeur spécifiée dans le Tableau S.11.

L'espace spécifié ci-dessus doit être égal à la longueur d'une ligne droite qui part de l'extrémité de la cosse à souder ou du serre-fil à pression auquel le câble est relié et être perpendiculaire à la paroi de l'*enveloppe* vers laquelle le câble est dirigé.

Si des barrières ou d'autres éléments empêchent de plier le câble à sa sortie du connecteur, la distance exigée par le Tableau S.11 doit être mesurée à partir de l'extrémité de la barrière. Une cosse ou un connecteur à borne doit être repositionné dans ces limites afin d'obtenir la distance de mesure la plus courte.

La dimension de fil utilisée pour déterminer l'espace de courbure du fil utilise la valeur de 125 % du courant nominal pleine charge du moteur. Voir le Tableau S.29 ou le Tableau S.30 pour connaître le courant nominal pleine charge des moteurs assignés en cheval-vapeur.

Tableau S.11 – Espace de courbure du câble aux bornes de l'équipement de conversion de puissance sous enveloppe

		Espace de courbure minimal, borne à paroi in (mm)					
Dimension de fil[a]		Nombre de fils par borne					
AWG ou kcmil	mm^2	1		2		3	
14 à 10	(2,1 à 5,3)	-	-	-	-	-	-
8 à 6	(8,4 à 13,3)	1-1/2	(38)	-	-	-	-
4 à 3	(21,2 à 26,7)	2	(51)	-	-	-	-
2	(33,6)	2-1/2	(64)	-	-	-	-
1	(42,4)	3	(76)	-	-	-	-
1/0	(53,5)	5	(127)	5	(127)	7	(178)
2/0	(67,4)	6	(152)	6	(152)	7-1/2	(191)
3/0	(85,0)	7	(178)	7	(178)	8	(203)
4/0	(107,2)	7	(178)	7	(178)	8-1/2	(216)
250	(127)	8	(203)	8	(203)	9	(229)
300	(152)	10	(254)	10	(254)	11	(279)
350	(177)	12	(305)	12	(305)	13	(330)
400	(203)	12	(305)	12	(305)	14	(356)
500	(253)	12	(305)	12	(305)	15	(381)
600	(304)	14	(356)	16	(406)	18	(457)
700	(355)	14	(356)	16	(406)	20	(508)
750 à 800	(380 à 405)	18	(457)	19	(483)	22	(559)
900	(456)	18	(457)	19	(483)	24	(610)
Si plus de trois conducteurs par borne sont prévus, l'espace de courbure doit être conforme aux tableaux correspondants pour les armoires et les boîtiers de l'Article 312 du National Electrical Code, ANSI/NFPA 70.							
[a] La dimension de fil doit être fondée sur S.4.11.11.2.							

Ajout d'un paragraphe supplémentaire à 4.11:

S.4.11.200 Généralités

S.4.11.200.1 Câblage du *circuit de commande*

Le câblage interne des circuits primaire et secondaire doit être équipé d'une protection supplémentaire lorsqu'il

a) est raccordé au côté charge de la protection du circuit de dérivation contre les courts-circuits (voir S.4.3.1),

b) se trouve dans un circuit qui intègre la bobine d'un contacteur de commande de moteur externe ou interne (pour le contournement, par exemple), et

c) est calibré de 22 AWG à 12 AWG (0,324 mm^2 à 3,3 mm^2).

Outre ce qui est indiqué dans les deux alinéas suivants, la protection supplémentaire du câblage exigée doit

d) se trouver à l'intérieur du *BDM/CDM*,

e) être assignée selon le Tableau S.13,

f) être prévue dans chaque conducteur non relié à la terre,

g) se trouver à plus de 12 in (305 mm) du point de raccordement du câblage à sa source de puissance,

h) être soit une protection supplémentaire ou un fusible de type circuit de dérivation conformément à la série UL 248, soit un disjoncteur de circuit de dérivation selon l'UL 489, et

i) être accompagné d'un marquage selon S.6.3.9.6.3 b).

Il n'est pas exigé d'inclure la protection supplémentaire indiquée dans le *BDM/CDM* s'il est livré depuis l'usine et qu'il satisfait à ce qui suit:

j) le fabricant met à disposition un kit conforme à la présente partie;

k) ce kit est évalué pour une installation sur site;

l) le *BDM/CDM* est marqué selon S.6.3.9.6.3 b) c).

Il n'est pas exigé de livrer la protection supplémentaire indiquée avec le *BDM/CDM* si le porte-fusible est inclus dans le *BDM/CDM* et que l'unité est marquée selon S.6.3.9.6.3 d).

Tableau S.12 – Protection contre les *surintensités*

Dimension de fil du circuit de commande, AWG mm^2		**Valeur assignée maximale du dispositif de protection** A
22	(0,32)	3
20	(0,52)	5
18	(0,82)	7
16	(1,3)	10
14	(2,1)	20
12	(3,3)	25

Pour les *BDM/CDM* dont le courant nominal de court-circuit est supérieur à 10 000 A, la protection supplémentaire du câblage doit être supérieure ou égale au courant nominal de court-circuit indiqué du *BDM/CDM*. Si des fusibles sont utilisés pour assurer cette protection, ils doivent être de classe CC, CF, G, J, L, R ou T et être fournis avec un porte-fusible de type circuit de dérivation approprié. Il n'est pas exigé que ces fusibles soient installés en usine.

La protection supplémentaire décrite en S.4.11.200.1 n’est pas exigée dans les cas suivants.

m) Si un câblage se trouve dans un *circuit de commande* à puissance limitée de Classe 1, dans un *circuit de commande* à distance de Classe 3 ou de Classe 2 (voir S.203.1.5): dans un circuit secondaire à limitation de tension/courant (voir S.203.1.6), à limitation d'énergie (voir S.203.1.1) ou d'impédance de l'imitation (voir S.203.1.8), aucune protection supplémentaire n'est exigée.

n) Il n'est pas exigé de prévoir une protection supplémentaire si le câblage mesure au moins 12 in (305 mm) de longueur.

o) Aucune protection supplémentaire n'est exigée si le câblage relié à une carte de circuit imprimé ne comporte aucune connexion externe au *BDM/CDM* ni d'aucun contact autre qu'occasionnel avec les parties isolées ou non isolées de polarité inverse ou avec les parties mises à la terre.

p) Si un disjoncteur à *déclenchement* instantané est utilisé ou destiné à être utilisé en tant que protection du circuit de dérivation contre les courts-circuits (voir S.4.3.1) et que ses caractéristiques assignées ou ses réglages ne dépassent pas la valeur applicable indiquée dans le Tableau S.13, aucune protection supplémentaire du câblage n'est exigée si le *BDM/CDM* est marqué selon S.6.3.9.6.3 a).

Tableau S.13 – Dispositif de protection prévu du circuit de dérivation

Dimension de fil du circuit de commande, AWG mm^2		Valeur assignée maximale du dispositif de protection du circuit de dérivation A	
		Conducteurs à l'intérieur de l'*enveloppe*	**Conducteurs à l'extérieur de l'*enveloppe***
22	(0,32)	12	3
20	(0,52)	20	5
18	(0,82)	25	7
16	(1,3)	40	10
14	(2,1)	100	45
12	(3,3)	120	60

S.4.11.200.2 Autres éléments que le câblage du *circuit de commande*

S.4.11.200.2.1 Protection primaire contre les *surintensités* (hors circuit de puissance)

Tout le câblage, y compris les bus de raccordement et les câbles d'interconnexion utilisés dans la distribution de l'énergie électrique primaire et entre les unités du *BDM/CDM/PDS* et tous les transformateurs et autres dispositifs de charge connectés au circuit primaire, doivent être protégés contre les brûlures et les dommages dont fait l'objet l'*isolation* résultant d'une condition de surcharge ou de court-circuit se produisant pendant le fonctionnement du *BDM/CDM/PDS*. Le dispositif de protection contre les *surintensités* doit être dimensionné en fonction des niveaux identifiés dans le Tableau S.12 et dans le Tableau S.13.

La protection référencée ci-dessus doit être assurée par des dispositifs de protection contre les *surintensités* faisant partie intégrante du *BDM/CDM/PDS* ou, si elle est assignée selon les alinéas suivants, par la protection associée au circuit de dérivation auquel le *BDM/CDM/PDS* est relié.

Les *dispositifs de protection contre les surintensités* fournis avec les *BDM/CDM/PDS* et qui satisfont aux exigences en matière de protection du circuit de dérivation selon le National Electrical Code, ANSI/NFPA 70 (les disjoncteurs ou les fusibles à cartouche de classe CC, CF, J, T, G, H, K, L, RK1 ou RK5, par exemple) satisfont aux exigences ci-dessus. D'autres types de dispositifs de protection contre les *surintensités* doivent être envisagés pour déterminer leur acceptabilité pour l'application.

Les caractéristiques assignées d'un dispositif de protection contre les *surintensités* en série avec câblage de connexion ne doivent pas dépasser:

a) pour les charges de moteur seules: 300 % du courant pleine charge du moteur observé dans des conditions normales de fonctionnement maximal du *système*;
b) pour les charges résistives et pour une combinaison de charges résistives et réactives, avec ou sans charge de moteur: 250 % du courant pleine charge du circuit en cours d'évaluation.

Le type de dispositif de protection contre les *surintensités* doit être prévu pour être utilisé lorsqu'il est directement alimenté par le circuit de dérivation auquel le *BDM/CDM/PDS* est raccordé, sauf si ce dernier intègre une protection supplémentaire prévue pour l'utilisation.

Un dispositif de protection contre les *surintensités* doit être raccordé entre le conducteur d'alimentation du circuit de dérivation non relié à la terre et la charge.

S.4.11.200.2.2 Dispositif de protection secondaire contre les *surintensités*

Tous les câbles d'interconnexion de circuit secondaire externe et tout le câblage de circuit secondaire entre les unités doivent être protégés contre les brûlures et les dommages dont fait l'objet l'*isolation* résultant d'une condition de surcharge ou de court-circuit se produisant pendant l'utilisation du *BDM/CDM/PDS*.

Le dispositif de protection contre les *surintensités* prévu dans le circuit primaire d'un transformateur est considéré comme assurant la protection du câblage du circuit secondaire lorsqu'il fonctionne pour protéger le circuit secondaire dans toutes les conditions de surcharge, y compris les courts-circuits.

Un conducteur fourni avec une protection contre les *surintensités* conforme au National Electrical Code, ANSI/NFPA 70, satisfait aux exigences du S.4.11.200.2.2.

Il n'est pas interdit d'utiliser des circuits secondaires dérivés d'alimentations ou d'autres sources lorsque le câblage transporte le courant maximal disponible de l'alimentation sans décoloration ou ramollissement de l'*isolation*, et que les alimentations ou les autres sources

a) sont par nature limitées, ou
b) intègrent des dispositifs de détection dont le fonctionnement donne le même résultat (prévention des brûlures et des dommages à l'*isolation* après une surcharge) ou coupe l'alimentation du *BDM/CDM/PDS*.

S.4.11.200.3 Fixation des *parties actives*

Outre ce qui est indiqué dans l’alinéa suivant, une *partie active non isolée*, y compris la borne, doit être fixée à sa surface de support selon une méthode autre qu'un frottement entre les surfaces. Il s'agit d'éviter qu'elle ne tourne ou se décale dans une position telle que ce type de mouvement réduise les *distances d’isolement* et *lignes de fuite* exigées.

Il n'est pas exigé d'empêcher un connecteur de borne à pression de pivoter lorsque le fait de tourner les bornes de 30° l'une vers l'autre, vers d'autres parties non isolées de polarité opposée ou vers des parties métalliques reliées à la terre ne réduit pas les *distances d’isolement* et *lignes de fuite* à une valeur inférieure à celles exigées.

Une tête de vis ou un écrou actif au dos d'un socle isolant ne doit pas se desserrer et doit être isolé ou espacé par rapport à la surface de montage. Pour ce faire

a) fraiser les parties sur au moins 1/8 in (3,2 mm) et les couvrir avec un matériau isolant étanche à l'eau qui ne se dégrade pas à 15 °C (27 °F) au-delà de sa température normale de fonctionnement et jusqu'à 65 °C (149 °F), ou
b) fixer lesdites parties et les isoler de la surface de montage par une barrière ou un moyen équivalent ou en prévoyant des *distances d'isolement* et des *lignes de fuite* indiquées dans le présent document.

S.4.12 Exigences mécaniques pour *les enveloppes*

Remplacement du 4.12:

S.4.12.200 Généralités

Aux États-Unis, les *enveloppes* doivent satisfaire aux exigences des normes UL 50 et UL 50E, sauf que l’Annex S complète, modifie ou remplace les exigences spécifiées dans l'UL 50 et l'UL 50E concernant les *enveloppes* fournies avec les équipements couverts par le présent document.

Aux États-Unis, les exigences relatives à l'*enveloppe* du moteur sont indiquées dans la série de norme UL 2111 et UL 1004.

S.4.12.201 Construction

S.4.12.201.1 Ajouts à la Section 6 de l'UL 50:2015

Les *BDM/CDM* dont les *enveloppes* sont incomplètes ou partielles sont évalués en tant que dispositifs ouverts en ce qui concerne les exigences de performances formulées dans le présent document.

Pour une *enveloppe* équipée de plusieurs compartiments, si le marquage est conforme à S.4.12.203.3, les composants individuels peuvent être évalués selon différentes exigences en matière de type d'*enveloppe* lorsque les compartiments sont totalement séparés par une paroi ou une barrière et que

a) l'assemblage est destiné à une utilisation intérieure et que les compartiments sont de type 1, 2, 4, 4X, 5, 6, 6P, 12, 12K, 13, ou

b) l'assemblage est destiné à une utilisation extérieure et que les compartiments sont de type 3, 3R, 3S, 4, 4X, 6 ou 6P.

S.4.12.201.2 Ajouts au Tableau 1 et au Tableau 2 de l'UL 50:2015

Une *enveloppe* 4X à utilisation intérieure uniquement est définie comme une *enveloppe* polymère prévue essentiellement pour un usage intérieur et assurant un degré de protection contre la poussière, les éclaboussures d'eau et l'eau amenée par un tuyau. Voir S.6.2.1 pour le marquage. Ces *enveloppes* ne sont pas destinées à des applications exposées au gel.

S.4.12.201.3 Classement environnemental lié aux performances de l'*enveloppe*

Outre ce qui est indiqué dans l’alinéa suivant, une *enveloppe* doit satisfaire aux exigences de performances liées au classement environnemental du Tableau 2: Essais de conception applicables de l'UL 50E:2020, qui s'appliquent au nombre caractéristique ou aux nombres caractéristiques avec lesquels l'*enveloppe* est marquée.

Une *enveloppe* de type 4X destinée uniquement à une utilisation intérieure et marquée selon S.6.2.1 doit satisfaire aux exigences relatives aux *enveloppes* de type 4X, avec les exceptions suivantes:

a) il n'est pas exigé de les soumettre à l'essai de gel extérieur de l'UL 50E;

b) il n'est pas exigé qu'une *enveloppe* polymère soit composée d'un matériau résistant à la lumière ultraviolette conformément à l'UL 50E.

Une *enveloppe* de type 12 peut utiliser des ouvertures de ventilation filtrées si elle satisfait aux exigences relatives aux *enveloppes* de type 12 de l'UL 50E.

Il est admis qu'un *BDM/CDM/PDS* autre que ceux de type 1 comporte des *parties actives isolées* à l'extérieur de l'enveloppe *principale* ou des segments de *parties actives* isolées en saillie à travers la paroi de l'*enveloppe* principale à condition que

c) les *parties actives* isolées externes ou en saillie se trouvent à l'intérieur d'un boîtier satisfaisant à toutes les exigences en matière d'*enveloppe* de type 1,

d) le matériau du boîtier satisfait aux exigences en la matière pour la désignation de type du *BDM/CDM/PDS*, et

e) les *parties actives* externes ou en saillie satisfont aux exigences environnementales pour la désignation de type du *BDM/CDM/PDS*.

NOTE L'*isolation* des *parties actives* peut être utilisée pour satisfaire aux exigences relatives au boîtier si elle satisfait aux exigences appropriées.

Si elle est équipée d'une ventilation forcée ou d'un autre type de ventilateur, des essais d'environnement doivent être réalisés séparément avec les ventilateurs associés sous tension et hors tension.

Les *parties actives* isolées ou segments de *parties actives isolées* qui traversent une *enveloppe* principale de type 12 doivent être protégées contre les projections de liquides non corrosifs et la poussière ambiante par l'une des méthodes suivantes.

f) Si la protection contre les projections de liquides non corrosifs est assurée par une *isolation électrique* intégrée aux *parties actives* isolées, le matériau isolant doit satisfaire aux exigences en matière de caractéristiques assignées de flamme, d'indice relatif de température (IRT), de résistance à l'inflammation du fil chaud (HWI), de résistance à l'inflammation de l'arc à courant élevé (HAI) et d'indice de résistance au cheminement (IRC) décrites en 4.4.7.8.2, ainsi qu'aux exigences de l'UL 746C, en ce qui concerne l'exposition à l'eau selon l'UL 746C Water Exposure and Immersion.

g) Si la protection contre les projections de liquide est assurée par des moyens mécaniques (cavité, canal, hotte ou protecteur, par exemple), la construction doit empêcher tout contact avec les liquides en question lorsque l'assemblage incluant l'*enveloppe* principale est soumis à l'essai d'égouttage de l'UL 50E, l'*enveloppe* étant montée dans toutes les orientations admises.

h) La protection contre la poussière ambiante doit être vérifiée dans le cadre de l'essai de poussière ou de l'essai à l'eau atomisée de l'UL 50E. À l'issue de l'essai de poussière ou de l'essai à l'eau atomisée, aucun contaminant (particules de poussière ou gouttelettes d'eau) n'est autorisé à entrer en contact avec les *parties actives* non isolées autres que celles des circuits à tension/courant limité comme cela est décrit à l'Article S.203 qui peuvent être exposées, par exemple, dans les enroulements d'un ventilateur de refroidissement alimenté par une source de tension/courant limité. Il est admis que les gouttelettes d'eau ou particules de poussière entrent en contact avec le matériau isolant. La pénétration de contaminant doit être vérifiée par démontage et *inspection visuelle* du 5.2.1 immédiatement après la fin de l'essai.

Les *parties actives* isolées ou segments de parties *actives isolées* qui traversent une *enveloppe* principale de type 4 ou 4X doivent être protégées contre la pluie, les éclaboussures d'eau et l'eau amenée par un tuyau par l'une des méthodes suivantes.

i) Si la protection contre la pluie, les éclaboussures d'eau et l'eau amenée par un tuyau est assurée par une *isolation électrique* intégrée aux *parties actives* isolées, le matériau *isolant* doit satisfaire aux exigences en matière de caractéristiques assignées de flamme, d'indice relatif de température (IRT), de résistance à l'inflammation du fil chaud (HWI), de résistance à l'inflammation de l'arc à courant élevé (HAI) et d'indice de résistance au cheminement (IRC) décrites en 4.4.7.8.2, ainsi qu'aux exigences de l'UL 746C, en ce qui concerne l'exposition à l'eau selon l'UL 746C.

j) Si la protection contre la pluie, les éclaboussures d'eau et l'eau amenée par un tuyau est assurée par des moyens mécaniques (cavité, canal, hotte ou protecteur, par exemple), la construction doit empêcher tout contact avec la pluie, les éclaboussures d'eau et l'eau amenée par un tuyau lorsque l'assemblage incluant l'*enveloppe* principale est soumis à l'essai Hosedown de l'UL 50E, l'*enveloppe* étant montée dans toutes les orientations admises.

k) La protection contre l'eau doit être vérifiée dans le cadre de l'essai Hosedown de l'UL 50E. À l'issue de l'essai Hosedown, aucun contact de l'eau n'est autorisé à entrer en contact avec les *parties actives* non isolées autres que celles des circuits à tension/courant limité, comme cela est décrit à l'Article S.203, qui peuvent être exposées, par exemple, dans les enroulements d'un ventilateur de refroidissement alimenté par une source de tension/courant limité. Il est admis que l'eau entre en contact avec le matériau isolant. La pénétration d'eau doit être vérifiée par démontage et *inspection visuelle* du 5.2.1 immédiatement après la fin de l'essai.

Un *capot* à pression faisant partie intégrante de l'*enveloppe* donnant accès aux *parties actives* non isolées et sans fixation séparée maniée par un outil ne doit présenter aucun moyen apparent permettant de le retirer (une languette, par exemple) et doit satisfaire à S.4.12.202.2.

S.4.12.201.4 Parties/*enveloppes* polymères

Ajout à 6.6 de l'UL 50:2015:

Si un adhésif fixe une partie obturant une ouverture dans une *enveloppe*, il doit satisfaire aux exigences relatives aux adhésifs de l'UL 746C. Il n'est pas exigé que l'adhésif d'une partie d'un *composant* satisfasse aux exigences si le dispositif satisfait aux exigences d'accessibilité et de l'*enveloppe* sans que la partie soit en place.

Il n'est pas exigé que l'adhésif d'une *enveloppe* de type 4X (intérieure uniquement) soit résistant à la lumière ultraviolette conformément à l'UL 746C.

S.4.12.201.5 Continuité électrique

Remplacement du 6.6.2 de l'UL 50:2015:

Les exigences du 4.4.4.2 de l'UL 50:2015 remplacent celles du 6.6.2 de l'UL 50:2015.

S.4.12.201.6 Ouvertures dans les *enveloppes*

S.4.12.201.6.1 Généralités

Ajout à 6.3 de l'UL 50:2015:

Une ouverture non utilisée pour la ventilation doit empêcher l'entrée d'une tige de 0,500 in (12,70 mm) de diamètre. Ces types d'ouvertures doivent satisfaire aux exigences du S.4.12.201.4 et du S.4.12.201.6.2.

Aucune couverture n'est exigée au fond d'une *enveloppe* de type 1, 2, 3R ou 3RX d'un contrôleur posé au sol si l'*enveloppe* se trouve dans les limites maximales de 6 in (152 mm) au-dessus du sol et si les *parties actives* à l'intérieur du dispositif se trouvent à moins de 6 in (152 mm) au-dessus de la partie la plus élevée du bord inférieur de l'*enveloppe*.

S.4.12.201.6.2 Accessibilité des *parties actives* ou mobiles

Pour réduire le risque de contact involontaire pouvant impliquer un risque de choc électrique ou de blessure, le calibre présenté à la Figure S.1 ou conforme à IP XXB de l'IEC 60529 (doigt d'essai assemblé selon l'IEC 61032:1997, calibre d'essai B selon la Figure M.2) ne doit pas entrer en contact avec une *partie active* ou un fil non isolé présentant des niveaux élevés de courant électrique ou avec des parties mobiles insérées dans une ouverture de l'*enveloppe*.

Dimensions en millimètres

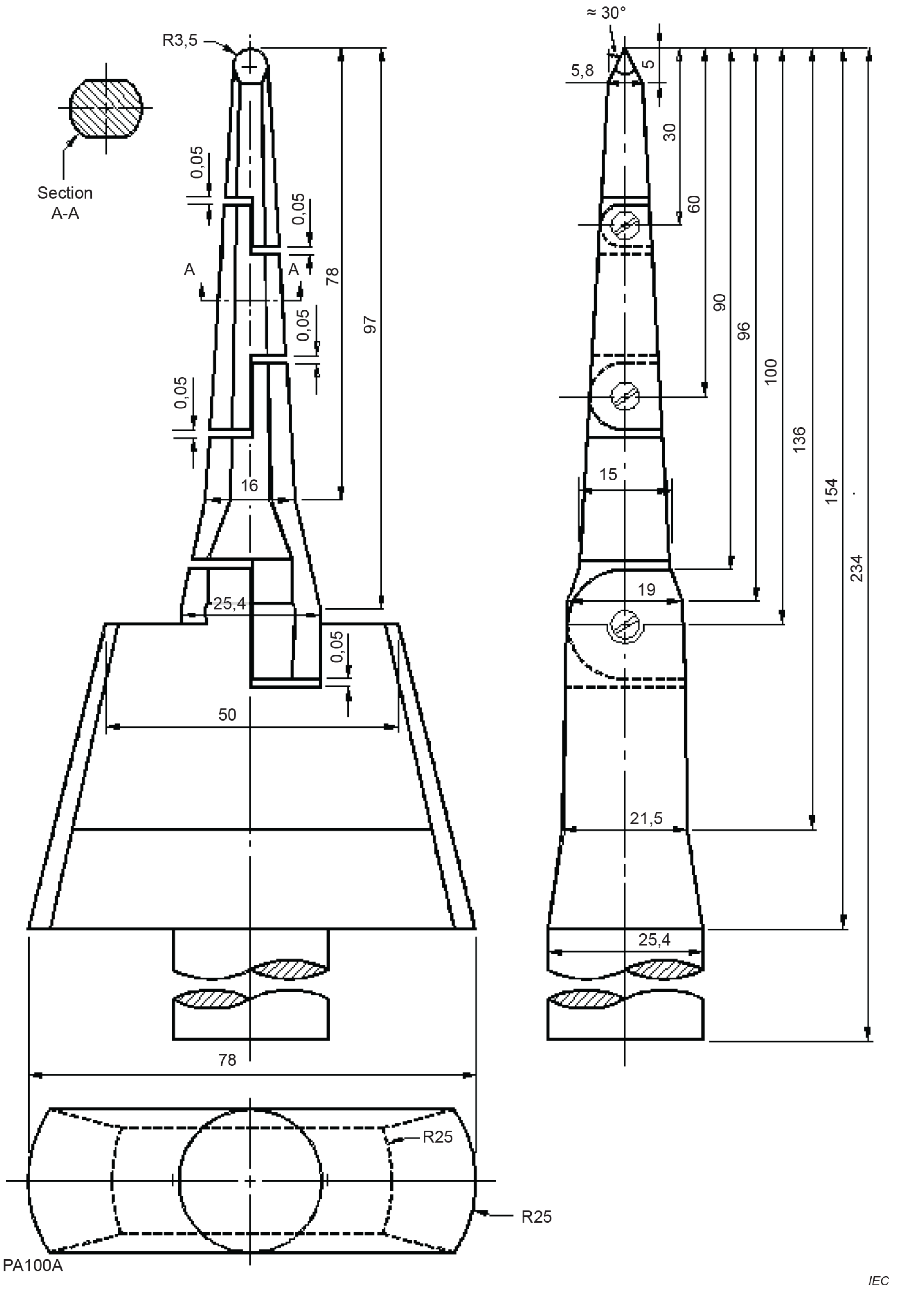


Figure S.1 – Calibre articulé avec butée

S.4.12.201.6.3 Ouvertures des équipements

Remplacement du 7.3.2 de l'UL 50E:2020:

Les ouvertures dans les *enveloppes* doivent être occupées par des dispositifs présentant les caractéristiques assignées environnementales adaptées spécifiées dans le Tableau S.14. Le dispositif peut être installé sur site si l'*enveloppe* est marquée selon 6.3.11.

Tableau S.14 – Ouvertures dans les *enveloppes*

Type d'*enveloppe*	Caractéristique assignée du type environnemental exigé pour les dispositifs de fermeture des ouvertures dans les *enveloppes*
2	2, 3, 3R, 3S, 4, 4X, 5, 6, 6P, 12, 13
3	3, 3S, 4, 4X, 6, 6P
3R	3, 3R, 3S, 4, 4X, 6, 6P
3S	3, 3S, 4, 4X, 6, 6P
4	4, 4X, 6, 6P
4X	4X
5	3, 3R, 3S, 4, 4X, 5, 6, 6P, 12, 13
6	6, 6P
6P	6P
12, 12K	12, 13
13	13

S.4.12.201.6.4 Ouvertures de ventilation

La longueur d'une grille de transfert ne doit pas dépasser 1 ft (305 mm). La surface d'une ouverture couverte pas une grille de transfert, un panneau perforé ou en lattes de métal déployées plus fin que l'*enveloppe* ne doit pas dépasser 1,39 ft^2 (0,129 m^2).

Le diamètre des fils d'un écran doit être d'au moins 0,05 in (1,30 mm) si la surface maximale des ouvertures de l'écran est de 0,05 in^2 (32,3 mm^2) et doit être d'au moins 0,08 in (2,03 mm) pour des ouvertures d'écran plus importantes.

Outre ce qui est indiqué dans l'alinéa suivant, la tôle d'acier perforée et la tôle d'acier utilisée pour les lattes de métal déployé doivent présenter une épaisseur d'au moins 0,04 in (1,07 mm) pour les ouvertures de maille ou les perforations de surface maximale de 0,5 in^2 (3,2 cm^2), et une épaisseur d'au moins 0,08 in (2,03 mm) pour les grandes ouvertures.

Dans un dispositif de petite taille dans lequel l'indentation d'un protecteur ou d'une *enveloppe* ne modifie pas la *distance d'isolement* entre les *parties actives* mobiles non isolées et le métal relié à la terre au point de compromettre les performances ou de réduire les *distances d'isolement* et *lignes de fuite* sous la valeur minimale spécifiée dans la norme de produit, des lattes en acier déployé d'épaisseur d'au moins 0,2 in (0,58 mm) peuvent être prévues si

a) la surface de la latte déployée sur un côté ou sur la surface du dispositif ainsi protégé ne dépasse pas 71,9 in^2 (464 cm^2) et que ses dimensions ne sont pas supérieures à 1 ft (305 mm), ou
b) la largeur de l'ouverture ainsi protégée ne dépasse pas 3,5 in (88,9 mm).

Une ouverture de ventilation dans une *enveloppe* ne doit pas permettre la pénétration d'une tige de 0,500 in (12,7 mm) de diamètre si les *parties actives* non isolées se trouvent à moins de 4 in (102 mm) de l'ouverture. Si la distance entre les *parties actives* non isolées et l'ouverture est supérieure à 4 in (102 mm), l'ouverture ne doit pas permettre la pénétration d'une tige de 0,750 in (19,05 mm) de diamètre.

S.4.12.201.6.5 Ventilation forcée

Lorsque la conformité à S.4.12.200 est exigée par S.4.4.200, si le corps d'un moteur de ventilateur polymère est accessible par les ouvertures dans l'*enveloppe* du *BDM/CDM*, le corps du moteur de ventilateur doit satisfaire aux exigences des essais d'*enveloppe* polymère du S.4.12.201.2. L'accessibilité doit être déterminée selon S.4.12.201.4.

Lorsque la conformité à S.4.12.200 est exigée par S.4.4.200, et outre ce qui est indiqué dans l'alinéa suivant, si les ouvertures dans l'*enveloppe* du *BDM/CDM* exposent le corps du moteur de ventilateur (en métal ou en polymère) à l'eau ou à la poussière pendant les essais selon S.4.12.201.1 (caractéristiques assignées environnementales liées aux performances de l'enveloppe), le corps du moteur de ventilateur doit protéger les enroulements du moteur de ventilateur contre cette exposition à l'eau ou à la poussière. L'aptitude du corps à protéger les enroulements doit être déterminée moteur de ventilateur en fonctionnement et à l'arrêt.

Il n'est pas exigé que les ouvertures d'une *enveloppe* de moteur de ventilateur satisfassent aux essais d'eau ou de poussière du S.4.12.201.1 (caractéristiques assignées environnementales liées aux performances de l'enveloppe) lorsque

a) l'*enveloppe* globale du *BDM/CDM* est divisée en deux parties distinctes: une partie contenant principalement le moteur de ventilateur et l'autre partie contenant la majorité des parties électriques, et
b) la partie de l'*enveloppe* globale qui contient le moteur de ventilateur est marquée du classement environnemental "type 1" quelle que soit le classement environnemental de l'autre partie de l'*enveloppe* globale.

S.4.12.201.6.6 Fenêtre d'observation

Le verre couvrant une fenêtre d'observation et faisant partie intégrante de l'*enveloppe* doit être fermement fixé de manière à ne pas être aisément déplacé en service et doit assurer la protection mécanique des parties *sous enveloppe*. L'épaisseur du verre prévu pour une ouverture de 4 in (102 mm) maximum dans toutes les dimensions ne doit pas être inférieure à 0,055 in (1,40 mm). L'épaisseur du verre prévu pour une ouverture de dimensions inférieures ou égales à 12 in (305 mm) ne doit pas être inférieure à 0,115 in (2,92 mm). Le verre utilisé pour couvrir une ouverture plus large doit présenter la résistance mécanique exigée et doit sinon être utilisable à cet effet.

S.4.12.201.7 Épaisseur des *enveloppes* en tôle

L'épaisseur d'une *enveloppe* en tôle doit être

a) supérieure ou égale à celle indiquée dans le Tableau S.15 et dans le Tableau S.16, ou

b) plus fine que celle spécifiée dans le Tableau S.15 et dans le Tableau S.16 et soumise à l'essai de flexion comparatif de la Section 8.1 de l'UL 50:2015 et à l'essai de flexion de la Section 8.2 de l'UL 50:2015.

Tableau S.15 – Ajout au Tableau 3 de l'UL 50:2015: Épaisseur de tôle des *enveloppes* – Acier au carbone ou acier inoxydable

Sans châssis support[a]		Avec châssis de support ou armature équivalente[a]		Épaisseur minimale
Largeur maximale[b]	Longueur maximale[c]	Largeur maximale[b]	Longueur maximale	Non revêtu
cm	cm	cm	cm	mm
10,2	Non limitée	15,9	Non limitée	0,51[d]
12,1	14,6	17,1	21,0	--
15,2	Non limitée	24,1	Non limitée	0,66[d]
17,8	22,2	25,4	31,8	--
20,3	Non limitée	30,5	Non limitée	0,81
22,9	29,2	33,0	40,6	--
31,8	Non limitée	49,5	Non limitée	1,07
35,6	45,7	53,3	63,5	--

[a] Voir S.4.12.201.7

[b] La largeur représente la plus petite cote d'une pièce rectangulaire en tôle faisant partie d'une *enveloppe*. Les surfaces voisines d'une *enveloppe* peuvent avoir des supports communs et n'être constituées que d'une seule feuille de tôle.

[c] "Non limitée" ne s'applique que si la surface possède un bord tombé d'au moins 12,7 mm ou lorsqu'elle est fixée aux surfaces voisines qui ne sont normalement pas démontées en cours d'utilisation.

[d] L'épaisseur de la tôle d'une *enveloppe* destinée à un usage extérieur ou en des points auxquels un *système* de câblage doit être connecté ne doit pas être inférieure à 0,81 mm.

Tableau S.16 – Ajout au Tableau 4 de l'UL 50: Épaisseur de tôle des *enveloppes* – aluminium, cuivre ou laiton

Sans châssis support[a]		Avec châssis de support ou armature équivalente[a]		Épaisseur minimale
Largeur maximale[b]	Longueur maximale[c]	Largeur maximale[b]	Longueur maximale	Non revêtu
cm	cm	cm	cm	mm
7,6	Non limitée	17,8	Non limitée	0,58[d]
8,9	10,2	21,6	24,1	--
10,2	Non limitée	25,4	Non limitée	0,74[d]
12,7	15,2	26,7	34,3	--
15,2	Non limitée d	35,6	Non limitée	0,91
16,5	20,3	38,1	45,7	--
20,3	Non limitée	48,3	Non limitée	1,14
24,1	29,2	53,3	63,5	--
30,5	Non limitée	71,1	Non limitée	1,47
35,6	40,6	76,2	94,0	--

[a] Voir S.4.12.201.7.

[b] La largeur représente la plus petite cote d'une pièce rectangulaire en tôle faisant partie d'une *enveloppe*. Les surfaces voisines d'une *enveloppe* peuvent avoir des supports communs et n'être constituées que d'une seule feuille de tôle.

[c] "Non limitée" ne s'applique que si la surface possède un bord tombé d'au moins 12,7 mm ou lorsqu'elle est fixée aux surfaces voisines qui ne sont normalement pas démontées en cours d'utilisation.

[d] L'épaisseur de la tôle de cuivre, de laiton ou d'aluminium d'une *enveloppe* destinée à un usage en extérieur ne doit pas être inférieure à 0,74 mm. L'épaisseur de la tôle de cuivre, de laiton ou d'aluminium d'une *enveloppe* en des points auxquels un *système* de câblage doit être connecté ne doit pas être inférieure à 1,14 mm.

S.4.12.201.7.1 Châssis support

Remplacement du 6.4.1.3 de l'UL 50:2015:

Les constructions ne comportant pas de châssis support sont les suivantes

a) une tôle à brides et bords profilés uniques – bords préformés,
b) une tôle ondulée ou nervurée,
c) une surface d'*enveloppe* non fermement fixée à un châssis, par exemple à l'aide d'attaches à ressort, et
d) une surface d'*enveloppe* dont l'un des bords ne repose pas sur le châssis.

S.4.12.201.8 Joints et fixations

La Section 6.4.2 de l'UL 50:2015 ne s'applique pas.

S.4.12.201.9 Encoches

La Section 6.4.3 de l'UL 50:2015 ne s'applique pas.

S.4.12.201.10 *Capots* et *portes*

S.4.12.201.10.1 Généralités

Si le remplacement d'un fusible ou d'un dispositif de protection contre les *surintensités* exige d'accéder à l'intérieur d'une *enveloppe*, cette dernière doit être équipée d'une *porte* d'accès à ce dispositif. Une *porte* doit également être prévue si l'accès à l'intérieur d'une *enveloppe* est exigé dans des conditions normales de fonctionnement.

Il est admis de remplacer un *capot* par une *porte* lorsque

a) l'accès est exigé uniquement en cas de brûlure d'un élément traversé par le courant ou de dispositifs analogues en cas de court-circuit t,
b) le seul fusible sous enveloppe est un fusible de commande/circuit, si le fusible et la charge de commande/circuit sont à l'intérieur de la même *enveloppe*,
c) le seul fusible sous enveloppe est un fusible de commande/circuit et la charge de commande/circuit est une charge fixe (une lampe témoin, par exemple),
d) des moyens ou des kits sont prévus pour régler tous les dispositifs de protection contre les surcharges depuis l'extérieur de l'enveloppe, un marquage étant prévu conformément à 6.2.2, et
e) le *capot* est verrouillé de manière à rendre le *BDM/CDM/PDS* inopérant lorsqu'il est retiré, et est marqué selon S.6.5.1.

S.4.12.201.10.2 Épaisseur de la *porte* et du *capot*

Remplacement du 6.7.2 de l'UL 50:2015:

L'épaisseur d'un *capot* ou d'une *porte* en tôle doit être

a) supérieure ou égale à celle indiquée dans le Tableau S.15 et dans le Tableau S.16, ou
b) plus fine que celle spécifiée dans le Tableau S.15 et dans le Tableau S.16 et soumise à l'essai de flexion de la Section 8.2 de l'UL 50:2015.

S.4.12.201.10.3 Moyens de fixation

Remplacement du 6.7.3 de l'UL 50:2015:

Une partie d'une *enveloppe* (une *porte* ou un *capot*, par exemple) doit être équipée de moyens permettant de la maintenir fermement en place (loquets, verrous, verrouillages ou vis, par exemple). Il n'est pas exigé qu'un *capot* à pression satisfaisant aux exigences du S.4.12.202.2 comporte des moyens de fixation supplémentaires.

S.4.12.201.10.4 Brides crantées

La Section 6.7.4 de l'UL 50:2015 ne s'applique pas.

S.4.12.201.10.5 Profondeur des brides (brides et feuillure)

Ajouts au 6.7.5 de l'UL 50:2015:

Une *porte* ou un *capot* donnant accès à un fusible ou à une partie d'un disjoncteur autre que la manette de commande doit satisfaire aux conditions suivantes.

a) La *porte* ou le *capot* doit comporter des brides sur toute la longueur des quatre bords. Une combinaison bride/feuillure peut être utilisée.
b) Pour une *enveloppe* de type 1 uniquement, l'écart entre les brides sur la *porte* ou le *capot* et la paroi extérieure peut être supérieur à celui spécifié si la construction satisfait aux exigences de performances applicables dans les conditions de court-circuit, ainsi qu'à S.4.12.201.4 (Accessibilité des *parties actives*).
c) Il n'est pas exigé que les brides sur la *porte* ou le *capot* correspondent étroitement sur la paroi extérieure si un joint d'étanchéité évalué pour l'application assure l'ajustement serré prévu.

S.4.12.201.10.6 Loquets et poignées

Remplacement du 6.9.1 de l'UL 50:2015:

Une *porte* doit être équipée d'un verrou ou d'une fixation multitour ou à tour partiel captive. Ce type de moyen de fixation doit être situé ou utilisé à plusieurs endroits, de manière à maintenir la *porte* fermée sur toute sa longueur. Une fixation captive doit être opérable à la main ou à l'aide d'un simple outil manuel (un tournevis, par exemple). Une *enveloppe* dont il n'est pas exigé qu'elle satisfasse à S.4.12.201.8 peut utiliser une *porte* sécurisée avec des fixations non captives.

Les exigences de 6.9.4 de l'UL 50:2015 ne s'appliquent pas.

Les exigences de 6.9.5 de l'UL 50:2015 ne s'appliquent pas.

Les exigences de 6.9.6 de l'UL 50:2015 ne s'appliquent pas.

S.4.12.201.11 Connexions aux *systèmes* de câblage

Ajout à 6.10.1.2 de l'UL 50:2015:

Si l'épaisseur du matériau de l'*enveloppe* est inférieure à 0,053 in (1,35 mm), l'épaisseur minimale de la fermeture peut être inférieure à 0,053 in (1,35 mm), mais inférieure à l'épaisseur du matériau de l'*enveloppe*.

Remplacement de 6.10.4.4 de l'UL 50:2015:

Si les filetages prévus pour la connexion du conduit ne sont pas taraudés dans tout le trou de la paroi d'une *enveloppe* ou de l'entrée de conduit, il ne doit pas y avoir moins de 3-1/2 filets complets dans le métal et les bords du trou d'entrée doivent être lisses et ronds.

Ajout à 6.10.2 de l'UL 50:2015:

Les dimensions des ouvertures défonçables sur l'enveloppe doivent être conformes au Tableau S.17.

Tableau S.17 – Dimensions des ouvertures défonçables

Dimension commerciale in	**Indicatif métrique**	**Diamètre de l'ouverture du conduit**			
		Minimum		**Maximum**	
		mm	(in)	mm	(in)
1/2	16	21,84	0,860	23,01	0,906
3/4	21	27,78	1,094	28,98	1,141
1	27	34,51	1,359	35,71	1,406
1-1/4	35	43,66	1,719	44,86	1,766
1-1/2	41	49,73	1,958	51,21	2,016
2	53	61,80	2,433	63,50	2,500
2-1/2	63	74,63	2,938	76,20	3,000
3	78	91,00	3,583	92,08	3,625
3-1/2	91	103,20	4,063	105,56	4,156
4	103	--	--	--	--

S.4.12.202 Performances

S.4.12.202.1 Généralités

Ajout à la Section 8.1 de l'UL 50:2015:

Chaque compartiment d'une *enveloppe* qui en comporte plusieurs doit faire l'objet des essais applicables pour sa désignation de type d'*enveloppe* respective. Il n'est pas exigé que la cloison intérieure entre les compartiments fasse directement l'objet de ces essais. Tous les matériaux de joints et de joints d'étanchéité entre les compartiments doivent être soumis aux essais d'environnement les plus sévères pour chaque compartiment.

Un moyen de fonctionnement externe (ceux prévus pour la déconnexion, un dispositif pilote ou une opération de réarmement, par exemple) monté sur ou à travers une *enveloppe* doit résister aux essais spécifiés pour l'*enveloppe*, sauf indication contraire.

S.4.12.202.2 Fixation d'un *capot* à pression

Les essais doivent être réalisés tels quels et après avoir retiré et remplacé le *capot* 10 fois.

Un *capot* à pression faisant partie intégrante de l'*enveloppe* donnant accès aux *parties actives* non isolées et sans fixation séparée maniée par un outil ne doit présenter aucun moyen apparent permettant de le retirer (une languette, par exemple) et doit satisfaire aux conditions suivantes.

a) Un *capot* qui peut se désengager de l'*enveloppe* en appliquant une force de pression avec une main ne doit pas être retiré lorsqu'une force de pression maximale de 14 lbf (62 N) est appliquée en deux points qui ne sont pas séparés de plus de 5 in (127 mm). La distance doit être mesurée par une bande étirée sur cette partie de la surface du *capot* englobée par la pomme de la main.

b) Un *capot* ne doit pas se désengager de l'*enveloppe* lorsqu'une force de traction directe de 14 lbf (62 N) est appliquée en saisissant le *capot* en deux endroits prévus à cet effet.

c) Un *capot* ne doit pas se désengager de l'*enveloppe* par une force de choc de 1 ft-lb (1,4 J) appliquée sur les faces accessibles du *capot* (un coup par face). Le choc doit être appliqué par une bille d'acier d'au moins 2 in (51 mm) de diamètre.

S.4.12.202.3 Essais de connexion du conduit métallique rigide de l'*enveloppe* polymère

S.4.12.202.3.1 Essai de serrage

Ajout à 8.6.3 de l'UL 50:2015:

Des valeurs de serrage inférieures peuvent être utilisées pour l'essai si un marquage est fourni selon S.4.12.203.

S.4.12.203 Marquage

S.4.12.203.1 Généralités

Remplacement de la Section 7 de l'UL 50:2015:

Les *enveloppes* polymères qui exigent une valeur de couple inférieure spécifiée en S.4.12.202.3.1 doivent faire l'objet du marquage suivant (ou un équivalent):

" Serrer à __N m. Un serrage excessif provoque la rupture de l'*enveloppe*."

Un *BDM/CDM/PDS* utilisant une fixation spéciale pour la connexion à un *système* de câblage particulier doit être marqué comme cela est spécifié en 6.3.7.

Un *BDM/CDM/PDS* qui a été évalué uniquement pour une installation avec un *système* de câblage sous enveloppe non métallique doit être marqué de manière à indiquer qu'il doit être installé avec ce type de *système* de câblage.

S.4.12.203.2 Marquages relatifs à l'environnement

Le 9.2.3 de l'UL 50E:2020 ne s'applique pas.

Les Sections 9.5.2 à 9.5.4 de l'UL 50E:2020 ne s'appliquent pas.

S.4.12.203.3 Marquage relatif à l'environnement des compartiments individuels

Les enveloppes avec plusieurs compartiments conformes à S.4.12.201.1 doivent comporter un marquage indiquant clairement les désignations de type de chacun des compartiments individuels.

S.4.12.204 Position des manettes de commande

Si un disjoncteur ou un commutateur est installé de sorte que le mouvement de la manette de commande, vertical ou rotatif, entre les positions marche et arrêt amène à une position au-dessus de l'autre, la position supérieure doit être celle de la marche. L'exigence ne s'applique pas au disjoncteur ou au commutateur fonctionnant horizontalement ou par rotation, les positions marche et arrêt étant au même niveau, ni à un dispositif de coupure ayant deux positions (un commutateur de transfert automatique ou un commutateur à deux directions, par exemple).

Tous les *BDM/CDM/PDS* posés au sol doivent satisfaire aux exigences suivantes. Les *BDM/CDM/PDS* montés au mur et dont la hauteur d'enveloppe dépasse 79 pouces (2,0 m) doivent être considérés comme des *BDM/CDM/PDS* posés au sol conformément à ces exigences.

Les poignées et boutons-poussoirs doivent être placés conformément à ce qui suit.

a) Chaque poignée de commutateur et de disjoncteur doit être installée de manière à ne pas se trouver à plus de 79 pouces (2,0 m) au-dessus du sol.
b) Les manettes de commande exigeant une force supérieure à 50 lbf (222 N) pour fonctionner ne doivent pas se trouver à plus de 66 in (1,7 m) en position ouverte ou fermée.

En déterminant la conformité de l'emplacement des poignées et boutons-poussoirs, des mesurages doivent être réalisés au centre du manche de la poignée, la poignée étant en position la plus élevée possible. Si le manche de la poignée n'est pas clairement défini, il doit être considéré comme se trouvant à 3 in (76 mm) de l'extrémité de la poignée.

Si le mécanisme d'un dispositif de coupure est tel que le fonctionnement automatique du commutateur ou le fonctionnement de dispositifs de déclenchement à distance ou automatique permet un mouvement brusque de la manette de commande, le mouvement de la poignée doit être limité ou la poignée doit être protégée de manière à ne blesser personne à proximité.

Ajout de paragraphes supplémentaires à l'Article 4:

S.4.200 Dispositifs auxiliaires

Les dispositifs auxiliaires tels que les programmateurs *portatifs* destinés à être utilisés uniquement de manière temporaire afin de diagnostiquer ou de programmer un *BDM/CDM/PDS*, doivent satisfaire aux exigences de l'UL 60950-1. Ces unités doivent être évaluées en tant que sous-système du *BDM/CDM/PDS*.

S.4.201 Accessoires

Un *BDM/CDM/PDS* comportant des moyens permettant d'utiliser un *accessoire* sur le terrain doit satisfaire aux exigences du présent document avec l'*accessoire* installé, ledit *accessoire* devant lui-même satisfaire aux exigences du *BDM/CDM/PDS* auquel il est destiné. Voir 6.2.2.

Dans le cadre de l'examen, un *accessoire* doit être soumis à l'essai et installé après essai. L'*accessoire* doit pouvoir être installé et les instructions doivent être détaillées et exactes. L'installation doit pouvoir être réalisée à l'aide d'outils aisément disponibles, sauf si un outil spécial est fourni avec l'*accessoire*.

S.4.202 Dispositions pour le montage

Des dispositions doivent être prises pour assurer un montage en toute sécurité du *BDM/CDM* sur une surface de support. Un boulon, une vis ou une autre pièce utilisée pour monter un *composant* du *BDM/CDM/PDS* ne doit pas être utilisé(e) pour fixer le *BDM/CDM/PDS* à la surface de support.

S.4.203 Condensateurs

Un condensateur de bus doit être adapté à la tension et à la température du circuit concerné. Cette caractéristique assignée doit reposer sur les caractéristiques assignées de *tension de fonctionnement* continue et de surtension transitoire (voir 4.4.7.3).

Un condensateur entre phases doit être adapté à la tension (racine carrée de 2 fois la valeur d'entrée) et à la température nominale du circuit concerné, et doit satisfaire à l'essai de tension en courant alternatif ou en courant continu en 5.2.3.4.

Outre ce qui est indiqué dans l'alinéa suivant, un condensateur de démarrage de moteur qui utilise un milieu diélectrique liquide plus combustible que le pyralène doit satisfaire aux exigences relatives au condensateur dans l'huile protégé de l'UL 810, y compris les conditions de *surintensité* en cas de défaut en fonction des valeurs assignées en court-circuit du *BDM/CDM*. Un condensateur de démarrage de moteur et un *composant* à semiconducteurs doivent être évalués dans le cadre de l'essai de défaillance de *composants* du 5.2.4.10.

Si le courant de défaut disponible est limité par d'autres *composants* dans le circuit (un enroulement de démarrage de moteur, par exemple), le condensateur peut être soumis à l'essai à l'aide d'un courant de défaut inférieur à la valeur exigée par l'essai de défaillance de *composants* du S.5.2.4.1, mais pas inférieur au courant établi en divisant la tension assignée du circuit par l'impédance des autres *composants*.

Il est exigé d'évaluer un condensateur autre qu'un condensateur de démarrage de moteur utilisant un milieu diélectrique liquide plus combustible que le pyralène, et un *composant* statique à semiconducteurs associé, dans le cadre de l'essai de défaillance de *composants* du 5.2.4.10.

S.5 Exigences d'essais

S.5.1 Généralités

S.5.1.1 Objectifs et classification des essais

S.5.1.2 Sélection des échantillons pour les essais

S.5.1.3 Séquence d'essais

S.5.1.4 Conditions de mise à la terre

S.5.1.5 Conditions générales d'essai

Ajout à 5.1.5:

Les essais doivent être réalisés à la fréquence assignée et à potentiel d'essai non inférieur à 120 V, 208 V, 240 V, 277 V, 480 V ou 600 V selon le cas pour les caractéristiques assignées de tension. Voir le Tableau S.18. L'essai de température doit être réalisé à un potentiel compris entre 90 % et 110 % du potentiel spécifié lors du réglage du courant de charge pour produire le chauffage normal maximal.

Tableau S.18 – Valeurs de tension pour les essais

Tension nominale du *BDM/CDM/PDS*[a]					
110 à 120	**220 à 240**	**254 à 277**	**380 à 415**	**440 à 480**	**560 à 600**
120	240	277	415	480	600
[a] Si la caractéristique assignée du *BDM/CDM/PDS* n'entre pas dans les limites de l'une des plages de tension assignées, il doit être soumis à l'essai à sa tension assignée.					

Sauf indication contraire, les essais doivent être réalisés à une *température ambiante* comprise entre 10 °C et 40 °C (50 °F et 104 °F). La *température ambiante* doit être déterminée à l'aide de thermomètres ou de thermocouples placés à côté du *BDM/CDM/PDS* soumis à l'essai.

Pendant les essais, le *BDM/CDM/PDS* doit être monté et câblé de manière à représenter l'utilisation prévue. Tous les blocs de *borne pour câblage externe* ou connecteurs de fil doivent être serrés à la valeur de serrage indiquée sur le produit.

Un *BDM/CDM* destiné à commander une charge de moteur à vitesse variable doit être soumis à l'essai en commandant

a) une charge équivalente à celle d'un moteur dont les caractéristiques assignées de tension, de fréquence et de courant correspondent aux caractéristiques assignées indiquées,
b) un moteur d'essai pouvant être chargé aux valeurs spécifiées, ou
c) une simulation du moteur d'essai par une charge passive composée de charges résistives ou inductives.

S.5.1.6 Conformité

Ajout à 5.1.6.

Les dispositifs ou *systèmes* entraînant la fin d'un essai doivent être par ailleurs évalués afin de déterminer leur pertinence pour l'application.

S.5.2 Spécifications des essais

S.5.2.1 *Inspections visuelles* (*essai de* type, *essai* individuel *de série* et *essai sur prélèvement)*

S.5.2.2 Essais mécaniques

S.5.2.2.1 *Essais* de *distances d'isolement* et de *lignes* de fuite (essai de *type)*

S.5.2.2.2 Essai de non-accessibilité *(essai de type*)

Remplacement du 5.2.2.2:

Pour réduire le risque de contact involontaire pouvant impliquer un risque de choc électrique ou de blessure, le calibre présenté en S.4.12.201.6.2 ne doit pas entrer en contact avec une *partie active* ou un fil non isolé présentant des niveaux élevés de courant électrique ou avec des parties mobiles insérées dans une ouverture de l'*enveloppe*.

Le calibre spécifié en S.4.12.201.6.2 doit être appliqué dans toutes les configurations possibles et, le cas échéant, la configuration doit être modifiée après insertion dans l'ouverture.

Le calibre spécifié en S.4.12.201.6.2 doit être appliqué avec une force ne dépassant pas 2,2 lbf (10 N). Le calibre doit être utilisé pour déterminer l'accessibilité permise par une ouverture et pas en tant qu'instrument de détermination de la résistance du matériau.

Le calibre spécifié en S.4.12.201.6.2 doit être inséré dans toutes les ouvertures comme cela est indiqué ci-dessus, y compris celles se trouvant en bas de l'unité. Pour une unité posée au sol, le calibre doit être inséré dans toutes les ouvertures du bas qui sont accessibles sans incliner, retourner ou déplacer l'unité de sa position d'installation prévue. Les unités autres que celles posées au sol doivent être déplacées de manière à ce que le bas soit accessible pour insérer le calibre.

S.5.2.2.3 Essai d'intégrité de l'enveloppe (classification IP) (*essai de type*)

Remplacement du 5.2.2.3:

Les *enveloppes* doivent satisfaire à S.4.12.

S.5.2.2.4 *Essai* d'intégrité de l'enveloppe *(essai de type*)

Remplacement du 5.2.2.4:

Les *enveloppes* doivent satisfaire à S.4.12.

S.5.2.2.5 Essai des BDM/CDM/PDS fixés *au* mur ou au plafond (*essai de type*)

Remplacement du 5.2.2.5:

Les *enveloppes* doivent satisfaire à S.4.12.

Ajout d'un paragraphe à 5.2.2:

S.5.2.2.200 Dispositifs connectés par un cordon et une prise

S.5.2.2.200.1 Essai de relâchement des contraintes

Cet essai remplace 5.2.2.7.

Le dispositif équipé d'un support d'attache comme en S.4.11.10.1 doit résister à une traction directe de 35 lbf (156 N) appliquée au cordon pendant 1 min. Aucun dommage ni déplacement du cordon ou des conducteurs ne doit être constaté. Les raccordements d'alimentation à l'intérieur du *BDM/CDM/PDS* doivent être déconnectés des bornes ou des épissures pendant l'essai.

Un fil de câblage externe doit résister sans être endommagé ou déplacé à une traction directe de

a) 20 lbf (90 N) appliquée pendant 1 min sur un fil partant de l'*enveloppe* et passant par un noyau ou un raccord, et de
b) 10 lbf (44,5 N) appliquée pendant 1 min à un fil de câblage externe à l'intérieur d'un compartiment de câblage ou d'une boîte de sortie de câble.

S.5.2.2.200.2 Essai de contrainte de refoulement

Pour déterminer la conformité à S.4.11.10.1, un produit doit être soumis à l'essai selon S.5.2.2.200.2 sans que l'une des conditions suivantes se produise:

a) expose le cordon d'alimentation à des dommages mécaniques;
b) expose le cordon d'alimentation à une température supérieure à celle pour lequel il est prévu;
c) réduit les *distances d'isolement* et les *lignes de fuite* (par rapport à un serre-câble métallique, par exemple) sous les valeurs exigées minimales;
d) endommage les connexions ou *composants* internes.

Le cordon ou fil d'alimentation doit être maintenu à 1 in (25,4 mm) de son point de sortie, puis être repoussé dans le produit. Si une traversée amovible qui s'étend à plus de 1 in (25,4 mm) est présente, elle doit être retirée avant l'essai. Si la traversée fait partie intégrante du cordon, l'essai doit être réalisé en conservant la traversée. Le cordon ou fil doit être repoussé dans le produit par incréments de 1 in (25,4 mm) tant que le cordon n'est pas refoulé ou que la force de poussée du cordon dans le produit ne dépasse pas 6 lbf (26,7 N). Le cordon ou fil d'alimentation à l'intérieur du produit doit être manipulé de manière à déterminer la conformité.

S.5.2.3 Essais électriques

S.5.2.3.1 Généralités

S.5.2.3.2 *Essai de tension* de tenue *aux chocs (essai* de *type, essai sur prélèvement*)

S.5.2.3.3 Alternative à *l'essai de tension* de tenue *aux chocs (essai* de *type, essai sur prélèvement*)

S.5.2.3.4 Essai de tension en courant alternatif *ou en courant continu* (*essai de type* et *individuel de série*)

S.5.2.3.4.1 But de l'essai

S.5.2.3.4.2 Valeur et type de la tension d'essai

Ajout à 5.2.3.4.2;

Les valeurs de tension d'essai sont déterminées à partir du Tableau S.19. Si la tension d'essai est appliquée pour évaluer la *protection renforcée*, sa valeur doit être conforme à 5.2.3.4.2.

Tableau S.19 – Tensions d'essai de tension en courant alternatif ou en courant continu

Tension nominale, V (valeur efficace) ou courant continu	**Tension d'essai** (valeur efficace) [a]
0 à 600 [b,c]	1 000 V + (2 x les caractéristiques assignées de tension nominale) [b,c]
601 à 1 500	2 000 V + (2,25 x les caractéristiques assignées de tension nominale)

[a] Courant alternatif ou 1,414 fois les valeurs du courant continu.

[b] Pour les *BDM/CDM/PDS* prévus pour plus de 250 V et destinés à être utilisés dans un emplacement relevant du degré de pollution 2, la tension d'essai peut être diminuée à 1 000 V. Cette tension d'essai réduite ne s'applique pas aux circuits internes autres que le bus à courant continu et qui fonctionnent à plus de 250 V.

[c] Pour les circuits secondaires isolés prévus pour 250 V au maximum et destinés à être utilisés dans un emplacement relevant du degré de pollution 2, la tension d'essai peut être diminuée à 1 000 V.

S.5.2.3.5 Essai de décharge partielle *(essai* de *type, essai sur prélèvement*)

S.5.2.3.6 *Essai d'impédance* de protection *(essai* de *type, essai individuel de série*)

S.5.2.3.7 *Essai de* mesure du courant *de* contact (*essai de type*)

S.5.2.3.8 Essai de décharge du *condensateur* (*essai de type*)

Ajout à 5.2.3.8:

La vérification doit uniquement être réalisée par un *essai de type.*

S.5.2.3.9 Essai de source de puissance *limitée* (*essai de type*)

S.5.2.3.10 Essai d'échauffement (essai *de type*)

Ajout à 5.2.3.10:

Les *BDM/CDM/PDS* de type ouvert et *sous enveloppe* doivent être soumis à l'essai à une *température ambiante* minimale estimée de 40 °C (104 °F), sauf si le *BDM/CDM/PDS* est marqué pour une *température ambiante* d'utilisation finale supérieure ou inférieure. Si le *BDM/CDM/PDS* est soumis à l'essai à une température autre que la température nominale d'utilisation finale, les températures mesurées maximales doivent faire l'objet d'une extrapolation linéaire pour déterminer la *température ambiante* d'utilisation finale prévue (par exemple, avec une *température ambiante* de 25 °C, 15 °C sont ajoutés à chaque mesurage de température si la *température ambiante* d'utilisation finale prévue est de 40 °C). Pour déterminer la *température ambiante*, plusieurs capteurs de température doivent être placés en différents endroits autour du *BDM/CDM/PDS* à une distance de 3 ft à 6 ft (0,9 m à 1,8 m). Les capteurs de température doivent être placés sur le trajet de l'air de refroidissement du *BDM/CDM/PDS* et doivent être protégés contre les courants d'air et les rayonnements de chaleur anormaux. La *température ambiante* doit être la moyenne des relevés de températures mesurées à intervalles réguliers pendant le dernier quart de la durée de l'essai.

Le courant assigné d'un *BDM/CDM/PDS* adapté uniquement en cheval-vapeur et pas en courant doit être comme cela est spécifié dans le Tableau S.29 et à l'Article S.204. Si le *BDM/CDM/PDS* est adapté en courant et en cheval-vapeur et que le courant nominal est différent de celui spécifié dans le Tableau S.29 et dans le Tableau S.30 pour le cheval-vapeur assigné, le courant de charge doit être la plus grande des deux valeurs de courant. Aucun dispositif ou circuit de protection ne doit se *déclencher* pendant l'essai.

S'il n'y a qu'une disposition en matière de connexion des bus de raccordement au *BDM/CDM* assigné à au moins 450 A, des bus de raccordement en cuivre de ¼ in (6,4 mm) d'épaisseur, de la largeur spécifiée dans le Tableau S.20 et d'au moins 4 ft (1,2 m) de longueur doivent être utilisés. La *distance d'isolement* et les *lignes de fuite* entre plusieurs bus de raccordement doivent être de ¼ in (6,4 mm) sans *distance d'isolement* et *lignes de fuite* plus importantes volontaire, sauf si cela est exigé au niveau des bornes individuelles du *BDM/CDM/PDS*.

Tableau S.20 – Largeur des bus de raccordement en cuivre

Caractéristiques assignées du produit A	Bus de raccordement par borne	Largeur du bus de raccordement	
		in	(mm)
450 à 600	1	2	(51)
601 à 1 000	1	3	(76)
1 001 à 1 200	1	4	(102)
1 201 à 1 600	2	3	(76)
1 601 à 2 000	2	4	(102)
2 001 à 2 500	2	5	(127)
	4	2-1/2	(64)
2 501 à 3 000	3	5	(127)
	4	4	(102)

La dimension de fil pour l'essai doit être la plus petite dimension présentant un courant permanent admissible d'au moins 125 % du courant d'essai. Voir le Tableau S.10 pour les courants permanents admissibles de dimension de fil.

La méthode du thermocouple pour mesurer la température comme cela est spécifié dans le Tableau 17 consiste à déterminer la température à l'aide d'un instrument de type potentiomètre et de thermocouples appliqués aux *parties accessibles* les plus chaudes. Les thermocouples doivent être constitués de fils ne dépassant pas 24 AWG (0,21 mm^2) d'au moins 30 AWG (0,05 mm^2). Les thermocouples et instruments associés doivent être exacts et étalonnés selon les pratiques de laboratoire normalisées. Le fil du thermocouple doit satisfaire aux exigences spécifiées dans la partie Tolérances sur les valeurs initiales des CEM par rapport aux tableaux de température (du Tableau 1 au Tableau 3) de l'ANSI/ASTM E230/E230M:2017.

La température de jonction maximale des semiconducteurs de puissance, comme cela est spécifié par le fabricant de semiconducteurs, ne doit pas être dépassée pendant l'essai de température. Pour déterminer la température de jonction, des températures de référence (boîtier, languette, dissipateur thermique ou parties similaires) doivent être mesurées, et la température de jonction doit être calculée en s'appuyant sur les données de dissipation de puissance et de résistance thermique fournies par le fabricant.

Ajout de paragraphes supplémentaires à 5.2.3*:*

S.5.2.3.200 Essai de tension en courant alternatif ou en courant continu de la ligne de production (*essai individuel de série*)

Les *BDM/CDM/PDS* équipés d'un cordon d'alimentation avec une prise de branchement à un circuit de tension nominale d'au moins 120 V doivent résister sans *claquage électrique*, dans le cadre d'un *essai individuel de série* de la ligne de production, à l'application d'un potentiel de courant alternatif à une fréquence comprise entre 40 Hz et 70 Hz ou d'un potentiel de courant continu entre le câblage principal (y compris les *composants* raccordés) et les *parties accessibles* en métal inerte susceptibles d'être mises sous tension.

L'essai de ligne de production doit être conforme à la condition A ou à la condition B du Tableau S.21.

Tableau S.21 – Conditions d'essai de ligne de production

Caractéristiques assignées du *BDM/CDM/PDS* V	**Condition A**			**Condition B**		
	Potentiel V courant alternatif	**Potentiel** V courant continu	**Durée** s	**Potentiel** V courant alternatif	**Potentiel** V courant continu	**Durée** s
250 ou moins	1 000	1 400	60	1 200	1 700	1
Plus de 250	1 000 + 2 × U[a]	1 400 + 2,8 × U[a]	60	1 200 + 2,4 × U[a]	1 700 + 3,4 × U[a]	1

[a] Tension marquée maximale.

Le potentiel d'essai peut être progressivement augmenté à la valeur exigée, mais la valeur totale doit être appliquée pendant 1 s ou 1 min, selon ce qui est exigé.

Le *BDM/CDM/PDS* peut être à la température de fonctionnement normal, à la température ambiante ou à une température intermédiaire pour l'essai.

L'essai doit être réalisé lorsque le *BDM/CDM/PDS* est totalement assemblé. Il n'est pas prévu de débrancher, de modifier ou de démonter le *BDM/CDM/PDS* pour l'essai.

a) Il n'est pas nécessaire qu'une partie (un *capot* à pression ou un bouton à ajustement par frottement, par exemple) qui gêne les performances de l'essai soit en place.
b) Si l'essai représente celui du *BDM/CDM/PDS* complet, il peut être réalisé avant l'assemblage. Un *composant* qui n'est pas inclus ne doit pas avoir d'impact sur les résultats en ce qui concerne la détermination du risque possible de choc électrique résultant d'un mauvais câblage, d'un *composant* défectueux, de *distances d'isolement* et de *lignes de fuite* insuffisantes et événements analogues.

Les *composants* à semiconducteurs statiques ou analogues qui peuvent être endommagés par un effet secondaire de l'essai peuvent être mis en court-circuit au moyen d'un shunt électrique ou l'essai peut être réalisé sans brancher le *composant*, à condition de maintenir les *distances d'isolement* et *lignes de fuite* du câblage et de la borne.

L'équipement d'essai doit comporter des moyens permettant d'indiquer le potentiel d'essai, d'un indicateur sonore ou visuel de *claquage électrique* et, pour les opérations automatisées ou de type de poste, d'un dispositif de réarmement manuel pour rétablir le *BDM/CDM/PDS* après un *claquage électrique* ou d'une fonction de rejet automatique de toutes les unités inacceptables. Si un éventuel essai de courant alternatif est appliqué, l'équipement d'essai doit inclure un transformateur ayant une sortie essentiellement sinusoïdale.

Si l'équipement d'essai est réglé pour générer la tension spécifiée et qu'une résistance de 120 000 Ω est reliée à la sortie, l'équipement d'essai doit indiquer des performances inacceptables dans les 5 s qui suivent. Une résistance supérieure à 120 000 Ω peut être utilisée pour indiquer des performances inacceptables lorsque le fabricant choisit d'utiliser un équipement d'essai présentant une sensibilité plus importante.

Si la sortie assignée de l'équipement d'essai est inférieure à 500 VA, l'équipement doit inclure un voltmètre dans le circuit de sortie pour indiquer directement le potentiel d'essai appliqué.

Si la sortie assignée de l'équipement d'essai est d'au moins 500 VA, le potentiel d'essai peut être indiqué par:

c) un voltmètre dans le circuit primaire ou dans un circuit d'enroulement tertiaire;
d) un commutateur marqué de manière à indiquer le potentiel d'essai; ou
e) dans le cas d'un équipement à une seule sortie de potentiel d'essai, un marquage placé à un endroit bien visible pour indiquer le potentiel d'essai.

Si aucun voltmètre d'indication n'est utilisé, l'équipement d'essai doit inclure des moyens visuels (un voyant, par exemple) pour signaler la présence de la tension d'essai au niveau de la sortie de l'équipement d'essai.

Un autre équipement d'essai peut être utilisé s'il se révèle en mesure de procéder au contrôle en usine prévu.

Pour l'essai, un nombre suffisant de dispositifs de commande doivent être fermés ou des applications séparées du potentiel d'essai être réalisées, de manière à soumettre à l'essai toutes les parties du circuit primaire.

S.5.2.3.201 Essai de continuité de la mise à la terre sur la ligne de production (*essais individuels de série*)

Un *BDM/CDM/PDS* équipé d'une prise de branchement ou d'un cordon d'alimentation avec une prise de branchement doit être soumis à l'essai (de ligne de production individuelle de série) afin de déterminer que la continuité de la mise à la terre est assurée entre la lame ou la broche de mise à la terre de la prise de branchement et les *parties accessibles* en métal inerte susceptibles d'être mises sous tension.

Un seul essai est nécessaire si la *partie accessible* en métal choisie est reliée de manière conductrice à toutes les autres *parties accessibles* en métal.

Un dispositif indicateur (ohmmètre, combinaison batterie/avertisseur sonore ou analogue) peut être utilisé pour déterminer la satisfaction à l'exigence de continuité de la mise à la terre.

S.5.2.3.202 Essai de continuité de polarisation sur la ligne de production – *BDM/CDM/PDS* connecté par cordon et prise (*essai individuel de série*)

Les *BDM/CDM/PDS* équipés d'une prise de branchement avec mise à la terre doivent maintenir la continuité électrique entre la lame de mise à la terre de la prise de branchement et toutes les *parties accessibles*, et doivent être vérifiés dans le cadre d'un *essai individuel de série* de la ligne de production. La continuité doit être déterminée dans le cadre d'un essai électrique.

S.5.2.3.203 Essai de joints serrés t

En ce qui concerne l'Article S.200, un joint serré entre deux isolateurs doit être soumis à l'essai à l'aide de deux échantillons.

a) Le joint serré du premier échantillon doit être ouvert jusqu'à produire un espace de 1/8 in (3,2 mm) de largeur. Pour ce faire, le dispositif de serrage est desserré ou un trou de 1/8 in (3,2 mm) de diamètre est percé au niveau du joint entre les isolateurs en un point présentant des *distances d'isolement* et *lignes de fuite* minimales entre les parties métalliques sur les côtés opposés du joint. Le trou percé ne doit pas réduire les *distances d'isolement* et *lignes de fuite* entre les parties de polarité opposée mesurées à travers les fissures entre les isolateurs. La tension de claquage de 50 Hz à 60 Hz qui traverse ce trou est ensuite déterminée en appliquant une tension qui augmente progressivement (500 V/s) jusqu'à ce qu'un claquage se produise.
b) Le second échantillon dont le joint serré est intact doit être soumis à une tension de 50 Hz à 60 Hz qui augmente progressivement voltage jusqu'à 110 % de la tension de claquage du S.5.2.3.203 a). Si la tension de claquage du S.5.2.3.203 a) est inférieure à 4 600 V en valeur efficace, la tension appliquée au second échantillon doit être augmentée à 5 000 V en valeur efficace et maintenue pendant 1 s. Le joint serré satisfait à l'exigence si aucun claquage ne s'est produit dans le second échantillon.

S.5.2.4 Essais de *fonctionnement anormal* et de défauts simulés

S.5.2.4.1 Généralités

Ajout à 5.2.4.1:

Le texte normatif du 5.2.4.1, points a), b) et c) ne s'applique pas. La note informative du point a) peut être utile.

Pour la méthode du 5.2.4.1, point a) en ce qui concerne l'essai de court-circuit seul du 5.2.4.5, un modèle peut servir de modèle représentatif à partir d'une série qui utilise le circuit de *protection intégrée contre les courts-circuits* pour la conformité à cet essai lorsque le modèle représentatif satisfait à S.4.3.2.2.

Les critères de l'échantillon à soumettre à l'essai d'une série de *BDM/CDM* qui utilise des fusibles ou des disjoncteurs pour assurer la conformité à cet essai s'appuient sur la comparaison des caractéristiques assignées du fusible ou du disjoncteur à celles du redresseur commandé en silicium (RCS) ou du dispositif de sortie du transistor de chaque modèle de la série (les caractéristiques assignées spécifiques à évaluer pour chaque modèle sont les valeurs de I^2t et de I_p).

Ajout de paragraphes supplémentaires à 5.2.4.1:

S.5.2.4.1.200 Mise à la terre

Le *BDM/CDM* doit être relié à la terre au moyen d'un fil présentant la section indiquée en S.4.4.4.3.1, et selon l'un des éléments suivants:

a) le câble de mise à la terre doit être relié entre l'*enveloppe* et la terre, la connexion de terre d'entrée principale étant retirée; ou
b) le câble de mise à la terre doit être relié entre l'*enveloppe* et la borne d'alimentation d'entrée principale qui semble présenter le moins de risque d'arc à la terre, la connexion de terre d'entrée principale étant retirée. Pour les *BDM/CDM* triphasés, la borne d'alimentation d'entrée principale qui semble présenter le moins de risque d'arc à la terre est la borne L2.

S.5.2.4.1.201 Protection du circuit de dérivation

La protection du circuit de dérivation doit satisfaire aux exigences suivantes.

a) Le *BDM/CDM* doit toujours être soumis à l'essai avec des fusibles, des disjoncteurs et des contrôleurs de moteur combinés de Type E, sauf si le *BDM/CDM* est marqué de manière à identifier qu'une protection du circuit de dérivation contre les courts-circuits doit être prévue conformément à l'une des dispositions suivantes:
   1) la protection doit être uniquement assurée par des fusibles (semiconducteurs ou non semiconducteurs), auquel cas aucun essai n'est exigé avec les disjoncteurs et les contrôleurs de moteur combinés de Type E;
   2) la protection doit être uniquement assurée par des fusibles (semiconducteurs ou non semiconducteurs) ou des disjoncteurs, auquel cas aucun essai n'est exigé avec les contrôleurs de moteur combinés de Type E;
   3) la protection doit être uniquement assurée par des fusibles (semiconducteurs ou non semiconducteurs) ou des contrôleurs de moteur combinés de Type E, auquel cas aucun essai n'est exigé avec les disjoncteurs;
   4) la protection doit être uniquement assurée par des disjoncteurs, auquel cas aucun essai n'est exigé avec les fusibles et les contrôleurs de moteur combinés de Type E.
b) Le dispositif de protection contre les *surintensités* utilisé pour cet essai doit être adapté à la protection du circuit de dérivation selon le National Electrical Code, NFPA 70 (les fusibles doivent satisfaire à la série de normes UL 248, les disjoncteurs doivent satisfaire à l'UL 489, et les contrôleurs de moteur combinés de type E doivent satisfaire à l'UL 508 et doit satisfaire au marquage du *BDM/CDM* spécifié en S.6.3.9.6. Si le marquage du *BDM/CDM* indique une caractéristique assignée de courant de défaut élevée, le dispositif de protection contre les *surintensités* doit également satisfaire à S.5.2.4.1.202.
c) Les essais réalisés avec des fusibles non semiconducteurs ne doivent pas remplacer les essais réalisés avec les disjoncteurs (à *déclenchement* à retardement ou à *déclenchement* instantané) ou avec les contrôleurs de moteur combinés de type E, sauf s'il peut être démontré que l'énergie résiduelle transitoire (I^2t) et le courant coupé limité de crête (I_p) du disjoncteur limiteur de courant à retardement et du contrôleur de moteur combiné de Type E exigés sont inférieurs à ceux des fusibles non semiconducteurs avec lesquels le *BDM/CDM* a été soumis à l'essai ou si le *BDM/CDM/PDS* en essai est équipé d'un circuit de protection statique contre les courts-circuits conforme à S.4.3.2.2 et qu'il peut être démontré par un essai que ce circuit fonctionne avant que la protection du circuit de dérivation ne se déclenche.
d) Les essais réalisés avec des fusibles non semiconducteurs ne doivent pas remplacer les essais réalisés avec des disjoncteurs (*déclenchement* à retardement ou instantané) ou avec des contrôleurs de moteur combinés de type E.
e) Même si le fonctionnement du circuit de protection intégrée contre les courts-circuits peut servir de résultat final pour interrompre l'essai de court-circuit (voir 5.2.4.5), la présence de ce circuit ne doit pas remplacer l'exigence relative aux fusibles, aux disjoncteurs ou aux contrôleurs de moteur combinés de Type E.
f) Les types de fusibles non semiconducteurs peuvent être adaptés à n'importe quelle classe évaluée pour la protection du circuit de dérivation, et leur tension nominale doit être au moins égale à la tension nominale d'entrée du *BDM/CDM.* Le courant nominal de ces

fusibles doit être égal à l'une des valeurs normalisées suivantes: 1, 3, 6, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 601, 700, 800, 1 000, 1 200, 1 600, 2 000, 2 500, 3 000, 4 000, 5 000 ou 6 000 A, et doit satisfaire à l'un des points suivants:

1) pour les *BDM/CDM* dont les courants de sortie assignés du moteur à pleine charge sont d'au moins 600 A, le courant nominal des fusibles doit être égal à 4 fois le courant nominal de sortie maximal du moteur à pleine charge;

2) pour les *BDM/CDM* dont les courants de sortie assignés du moteur à pleine charge sont supérieurs à 600 A, le courant nominal des fusibles doit être égal à 3 fois le courant nominal de sortie maximal du moteur à pleine charge;

3) quel que soit le courant nominal de sortie du moteur à pleine charge d'un *BDM/CDM*, le courant nominal du fusible peut être inférieur à celui spécifié en a) ou b) ci-dessus si le *BDM/CDM* est marqué selon S.6.3.9.6.1.

Si la valeur calculée du fusible est comprise entre les deux caractéristiques assignées normalisées, la caractéristique assignée normalisée la plus proche inférieure à la valeur calculée doit s'appliquer.

g) La tension nominale des types de fusibles à semiconducteurs doit être au moins égale à la tension nominale d'entrée du *BDM/CDM*, leur courant nominal pouvant être quelconque. Un *BDM/CDM* qui utilise des types de fusibles à semiconducteurs doit être marqué selon S.6.3.9.6.1.

h) La tension nominale des disjoncteurs à retardement doit être au moins égale à celle du *BDM/CDM.* Le courant nominal de ces disjoncteurs doit être égal à l'une des valeurs normalisées suivantes: 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 700, 800, 1 000, 1 200, 1 600, 2 000, 2 500, 3 000, 4 000, 5 000 ou 6 000 A, et satisfaire à l'un des points suivants:

1) pour les *BDM/CDM* dont les courants de sortie assignés du moteur à pleine charge sont d'au moins 100 A, le courant nominal du disjoncteur doit être égal à 4 fois le courant nominal de sortie maximal du moteur à pleine charge; ou

2) pour les *BDM/CDM* dont les courants de sortie assignés du moteur à pleine charge sont supérieurs à 100 A, le courant nominal du disjoncteur doit être égal à 3 fois le courant nominal de sortie maximal du moteur à pleine charge; ou

3) quel que soit le courant nominal de sortie du moteur à pleine charge du *BDM/CDM*, le courant nominal du disjoncteur peut être inférieur à celui spécifié en a) ou b) ci-dessus si le *BDM/CDM* est marqué selon S.6.3.9.6.1.

Si la valeur calculée du disjoncteur est comprise entre les deux caractéristiques assignées normalisées, la caractéristique assignée normalisée la plus proche inférieure à la valeur calculée doit s'appliquer. Si la valeur calculée du disjoncteur est inférieure à 15 A, un disjoncteur assigné à 15 A doit être utilisé.

i) La tension nominale des disjoncteurs à *déclenchement* instantané doit être au moins égale à la tension nominale d'entrée du *BDM/CDM*, leur courant nominal pouvant être quelconque si le *BDM/CDM* est marqué selon S.6.3.9.6.1.

j) Un *BDM/CDM* utilisant des fusibles non semiconducteurs ou des disjoncteurs à retardement dimensionnés selon S.5.2.4.1.201 f)1),S.5.2.4.1.201 f)2),S.5.2.4.1.201 h)1), ou S.5.2.4.1.201 h)2), n'exige aucun marquage pour indiquer le fabricant, le numéro de modèle ou les caractéristiques assignées du fusible ou du disjoncteur.

k) Les contrôleurs de moteur combinés de type E sont assignés en volts et en cheval-vapeur. Pour déterminer le courant nominal du contrôleur de moteur combiné de type E, voir le Tableau S.29 et relever le courant nominal à pleine charge à l'intersection des colonnes appropriées de tension et de phase et de la ligne de cheval-vapeur. Si le paramètre de surcharge du contrôleur de moteur combiné de type E est réglable, le courant nominal à pleine charge du contrôleur de moteur combiné de type E est défini comme étant le courant maximum sur lequel contrôleur peut être réglé.

l) Le courant nominal à pleine charge du contrôleur de moteur combiné de Type E ne doit pas être inférieur au courant d'entrée assigné du contrôleur du *BDM/CDM*.

m) Les essais de court-circuit d'un contrôleur de moteur combiné de Type E doivent être réalisés avec le contrôleur à ses réglages maximaux.

n) Le pouvoir d'interruption en court-circuit du fusible, du disjoncteur à retardement ou du contrôleur de moteur combiné de Type E ne doit pas être inférieur à la valeur assignée de court-circuit du contrôleur du *BDM/CDM*.

S.5.2.4.1.202 Raccordement de câblage d'entrée/sortie

Ces exigences remplacent celles relatives au câblage d'entrée/sortie de tous les paragraphes du 5.2.4.

Chaque *BDM/CDM* doit être soumis à l'essai avec un fil de longueur maximale de 4 ft (1,2 m) raccordé à chaque borne d'entrée et de sortie. La longueur du câblage d'essai d'entrée/sortie peut être supérieure à 4 ft (1,2 m) s'il se trouve dans le circuit d'essai pendant son étalonnage.

La dimension de fil du câblage d'entrée et de sortie doit être conforme au Tableau S.10 avec le courant permanent admissible exigé du câblage en s'appuyant sur la température nominale du fil indiquée sur le marquage (60 °C ou 75 °C) et chacun des points suivants:

a) le câblage de puissance d'entrée principal doit être calibré pour 125 % du courant de sortie assigné du moteur à pleine charge;

b) tous les autres câblages d'entrée doivent être calibrés pour 100 % du courant à pleine charge prévu maximal;

c) le câblage de puissance de sortie principal doit être calibré pour 125 % du courant à pleine charge assigné ou pour 125 % du courant de sortie du moteur à pleine charge indiqué dans le Tableau S.29 ou dans le Tableau S.30, en fonction de la caractéristique assignée de cheval-vapeur; et

d) tous les autres câblages de sortie doivent être calibrés pour 100 % du courant à pleine charge prévu maximal.

Le type d'isolation de fil doit être T ou TW pour un câblage à 60 °C et doit être THW ou THWN pour un câblage à 75 °C.

Pour les *BDM/CDM* adaptés à plus de 200 hp (150 kW), les connexions d'alimentation d'entrée/sortie principales doivent être conformes aux exigences ci-dessus ou peuvent être composées de bus de raccordement dont la section est équivalente au câblage exigé. Les bus de raccordement peuvent se trouver dans le circuit d'essai pendant leur étalonnage.

Le câblage d'entrée et de sortie peut alors être acheminé par un conduit de longueur comprise entre 10 in et 12 in (250 mm et 305 mm) installé sur l'*enveloppe*. Si aucun conduit n'est utilisé, le fil doit être acheminé par une traversée appropriée à la dimension des conducteurs.

Les extrémités du conduit, l'ouverture de la traversée ou les ouvertures autour du bus de raccordement doivent être obturées par du coton hydrophile.

S.5.2.4.1.203 Séquence des essais

Les exigences suivantes s'appliquent à l'essai de court-circuit en sortie et à l'essai de défaillance de *composants*. Elles complètent les exigences du 5.2.4.5 et du 5.2.4.10.3.

Si l'essai est interrompu par le fonctionnement d'un *circuit électronique de protection contre les courts-circuits en sortie de puissance,* ce circuit doit faire l'objet des exigences du 5.2.4.7. Si le circuit de protection intégrée contre les courts-circuits ne fait pas l'objet des exigences du 5.2.4.7, il doit être écarté avant de procéder à l'essai.

Si l'essai est interrompu par l'ouverture d'un *dispositif de protection contre les courts-circuits*, ce dispositif doit

a) être un fusible conforme à la série de normes UL 248 relatives aux fusibles,

b) être un disjoncteur conforme à l'UL 489, ou

c) être un contrôleur de moteur combiné autoprotégé conforme à l'UL 60947-4-1.

Il est admis que l'essai soit interrompu par la défaillance en circuit ouvert d'un dispositif à semiconducteurs.

S.5.2.4.2 Tension, courant et fréquence d'alimentation

Ajout à 5.2.4.2:

Les essais de défaillance de *composants* et de court-circuit doivent être réalisés aux valeurs d'essai du Tableau 36. Les valeurs du Tableau 36 sont considérées comme les valeurs de courant de défaut normalisées. Si une valeur assignée de court-circuit est supérieure à la valeur normalisée de l'essai de courant de défaut, le *BDM/CDM/PDS* doit également satisfaire à a) et b). L'aptitude du circuit pour tous les essais doit être vérifiée selon l'étalonnage du circuit d'essai de court-circuit, S.5.2.4.2.200.

a) Une série *BDM/CDM* dont la valeur assignée de court-circuit est supérieure à la valeur normalisée de l'essai de courant de défaut du Tableau 36 doit satisfaire aux exigences de l'essai de court-circuit du S.5.2.4.2 pour l'essai de courants de défaut normalisés et de court-circuit – courants de défaut élevés, S.5.2.4.2.202.

b) Une série *BDM/CDM* dont la valeur assignée de court-circuit est supérieure à la valeur normalisée de l'essai de courant de défaut du Tableau 36 doit satisfaire aux exigences de l'essai de défaillance de *composants* du S.5.2.4.2 pour l'essai de courants de défaut normalisés et l'essai de défaillance de *composants* – courants de défaut élevés, S.5.2.4.2.202.

Une série *BDM/CDM* satisfait à l'essai de court-circuit – courants de défaut élevés, S.5.2.4.2.202, sans essai supplémentaire lorsque

c) la série *BDM/CDM* utilise un *circuit de protection intégrée contre les courts-circuits* pour la conformité à l'essai de court-circuit de courant de défaut normalisé, et

d) le circuit de protection intégrée contre les courts-circuits est utilisé selon S.4.3.2.2.

Si l'analyse du circuit indique que l'énergie de court-circuit disponible (en fonction de la valeur assignée de court-circuit marquée) n'a pas d'impact important sur les résultats de l'essai de défaillance de *composants* qu'une énergie de court-circuit disponible inférieure, l'essai de défaillance de *composants* peut être réalisé au niveau d'énergie inférieur.

L'analyse du circuit selon 4.2 doit prendre en considération:

- éclatement I^2t des conducteurs et des *composants*;
- identification du trajet de courant de défaut dans le *BDM/CDM/PDS*;
- possibilité et étendue des défaillances en cascade;
- nature de la défaillance en fonction de l'emplacement physique (proximité d'autres *composants* essentiels, barrières, *distances d'isolement*, *lignes de fuite*, ouvertures de ventilation, par exemple);
- identification de toutes les sources d'énergie (*réseau*, condensateurs, batteries, moteur, etc.) dans le circuit;
- pour le *réseau*, prendre en considération la configuration du circuit d'alimentation et de la mise à la terre (en Y, en étoile, IT, etc.);
- l'*enveloppe* (dimension, matériau, structure, ouvertures, etc.);

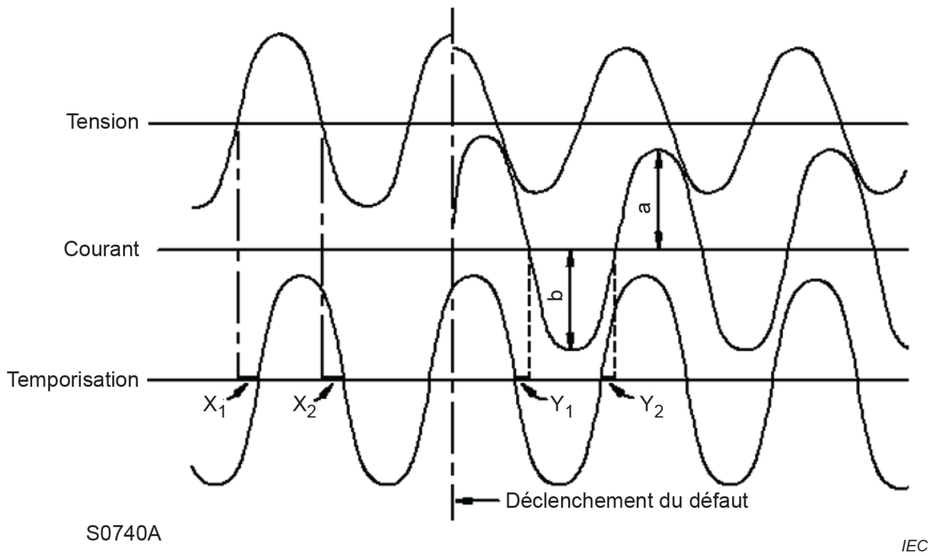
- les types et les caractéristiques assignées du SCPD spécifié à utiliser avec le *BDM/CDM/PDS*;
- la linéarité spécifiée des *composants* de limitation du courant (externes et internes) par rapport au courant de défaut disponible;
- les effets de plusieurs caractéristiques assignées du *PDS* (relation de puissance nominale et de tension nominale);
- la variation des *composants* d'une famille de *BDM/CDM*;
- la variation maximale de l'impédance, de la fréquence et de la tension du *réseau* par rapport aux applications de produits spécifiées/publiées (utilisation de transformateur, etc.);
- des essais peuvent être nécessaires pour valider les parties de l'analyse du circuit.

Ajout de paragraphes supplémentaires à 5.2.4.2:

S.5.2.4.2.200 Étalonnage des circuits d'essai de court-circuit à 10 000 A au maximum

Pour un circuit en courant alternatif destiné à délivrer 10 000 A au maximum, le courant doit être déterminé selon l'un des éléments suivants.

a) Pour un circuit d'essai triphasé, le courant doit être déterminé en calculant la moyenne des valeurs efficaces du premier cycle complet de courant dans chacune des trois phases.
b) Pour un circuit monophasé, le courant doit être égal à la valeur efficace du premier cycle complet (voir la Figure S.2) lorsque le circuit est fermé pour générer une forme d'onde de courant symétrique. La composante continue ne doit pas être ajoutée à la valeur obtenue lorsque la mesure est réalisée comme cela est indiqué. Pour obtenir la forme d'onde symétrique exigée d'un circuit monophasé, une fermeture commandée est la plus souvent utilisée, même s'il n'est pas interdit d'utiliser de méthodes de fermeture aléatoire.
c) Pour un circuit d'essai monophasé ou triphasé, une évaluation analytique qui démontre le courant disponible de manière pertinente peut être utilisée.



Courant = [$(a+b)$/2] (étalonnage en valeur efficace de l'élément d'instrument)

Figure S.2 – Détermination du courant pour des circuits de 10 000 A au maximum

S.5.2.4.2.201 Étalonnage des circuits d'essai de court-circuit supérieurs à 10 000 A

Pour un circuit en courant alternatif destiné à délivrer plus de 10 000 A, le courant doit être déterminé selon l'un des éléments suivants:

a) selon les exigences du S.5.2.4.2.201, les instruments utilisés pour mesurer ces circuits d'essai de plus de 10 000 A doivent satisfaire aux exigences du S.5.2.4.2.201; ou

b) pour un circuit d'essai monophasé ou triphasé, une évaluation analytique qui démontre le courant disponible de manière pertinente peut être utilisée.

Le courant symétrique en valeur efficace doit être déterminé, avec les bornes d'alimentation mises en court-circuit, en mesurant la composante alternative de l'onde à un 1/2 cycle (sur la base de l'onde de synchronisation de fréquence d'essai) après le début du court-circuit. Le courant doit être calculé selon la Figure D.1 de l'ANSI/IEEE C37.90-2005.

Pour un circuit d'essai triphasé, le courant symétrique en valeur efficace doit être égal à la moyenne des courants dans les trois phases. Le courant symétrique en valeur efficace de l'une des phases ne doit pas être inférieur à 90 % du courant d'essai exigé.

Le circuit d'essai et ses transitoires doivent être tels que

c) 3 cycles après le début du court-circuit, la composante alternative symétrique du courant n'est pas inférieure à 90 % de la composante alternative symétrique du courant à la fin du premier ½ cycle, ou

d) la composante alternative symétrique du courant au moment auquel le dispositif de protection contre les *surintensités* interrompt le circuit d'essai est égale à au moins 100 % de la caractéristique assignée pour laquelle le contrôleur est soumis à l'essai. Dans les circuits triphasés, la composante alternative symétrique du courant des trois phases doit être moyennée.

La tension de rétablissement doit être au moins égale à la tension assignée du contrôleur. La valeur de crête de la tension de rétablissement dans le premier demi-cycle complet après la coupure et pour les cinq crêtes suivantes successives doit être au moins égale à 1,414 fois la valeur efficace de la tension assignée du contrôleur. Chacune des crêtes ne doit pas se déplacer de plus ±10° électriques par rapport aux valeurs de crête de la tension de rétablissement en circuit ouvert, c'est-à-dire par rapport à sa position normale sur une onde sinusoïdale. La moyenne des valeurs instantanées de la tension de rétablissement sur chacun des six premiers demi-cycles mesurés en des points à 45° et 135° sur l'onde ne doit pas être inférieure à 85 % de la valeur *efficace* de la tension assignée du contrôleur. La valeur instantanée de la tension de rétablissement en des points à 45° et 135° de chacun des six premiers demi-cycles ne doit en aucun cas être inférieure à 75 % de la valeur *efficace* de la tension assignée du contrôleur.

En l'absence d'atténuation ou de déphasage du premier cycle complet de l'onde de tension de rétablissement comparée à l'onde de tension secondaire en circuit ouvert avant que le courant ne circule dans un circuit qui utilise une fermeture secondaire, le mesurage détaillé des caractéristiques de tension de rétablissement indiquées ci-dessus n'est pas exigé.

Le galvanomètre d'un oscillographe magnétique utilisé pour enregistrer la tension et le courant pendant l'étalonnage du circuit et pendant l'essai doit présenter une réponse en fréquence plate (±5 %) comprise entre 50 Hz et 1 200 Hz. Pour les fusibles rapides, les limiteurs de courant ou les protecteurs de moteur contre les courts-circuits, il est souvent exigé qu'un galvanomètre présente une réponse en fréquence plate comprise entre 50 Hz et 9 000 Hz ou l'utilisation d'un oscilloscope est exigée pour obtenir des valeurs de courant de crête exactes (I_p), et l'énergie limitée (I^2t).

Les galvanomètres doivent être étalonnés comme suit.

e) Si un shunt est utilisé pour déterminer les caractéristiques du circuit, une tension d'étalonnage en courant continu est en principe utilisée. La tension appliquée au circuit du galvanomètre de l'oscillographe doit entraîner une déviation du galvanomètre équivalente à celle qui est prévue lorsque le même circuit du galvanomètre est connecté au shunt et que le courant de court-circuit nominal circule. La tension doit être appliquée de manière à ce que le galvanomètre dévie dans les deux directions. Des étalonnages supplémentaires doivent être réalisés à 50 % et 150 % de la tension utilisée pour obtenir la déviation indiquée ci-dessus, sauf que si la déviation maximale prévue est inférieure à 150 % (un circuit monophasé fermé symétriquement, par exemple), un autre point d'étalonnage utilisable doit être choisi. La sensibilité du circuit du galvanomètre en volts par pouce (ou millimètre) doit être déterminée à partir de la déviation mesurée dans chaque cas et la moyenne des résultats des six essais être calculée. Les ampères crêtes par pouce (ou millimètre) sont obtenus en divisant la sensibilité par la résistance du shunt. Ce facteur de multiplication doit être utilisé pour déterminer le courant en valeur efficace décrit précédemment en S.5.2.4.2.201.

f) Un potentiel d'onde sinusoïdale de 50 Hz à 60 Hz peut être utilisé pour étalonner le circuit du galvanomètre, en utilisant la même méthode générale décrite en e). Le facteur obtenu doit être multiplié par 1,414.

g) Si un transformateur de courant est utilisé pour déterminer les caractéristiques du circuit, un courant alternatif doit être utilisé pour étalonner le circuit du galvanomètre. La valeur du courant appliqué au circuit du galvanomètre doit entraîner une déviation du galvanomètre équivalente à celle qui est prévue lorsque le même galvanomètre est connecté au secondaire du transformateur de courant et que le courant de court-circuit nominal circule dans le primaire. Des étalonnages supplémentaires doivent être réalisés à 50 % et 150 % du courant utilisé pour obtenir la déviation indiquée ci-dessus, sauf que si la déviation maximale prévue est inférieure à 150 % (un circuit monophasé fermé symétriquement, par exemple), un autre point d'étalonnage utilisable doit être choisi. La sensibilité du circuit du galvanomètre en ampères par pouce (ou millimètre) en valeur efficace doit être déterminée dans chaque cas et la moyenne des résultats être calculée. La sensibilité moyenne doit être multipliée par le rapport du transformateur de courant et par 1,414 pour obtenir les ampères de crête par pouce. Cette constante doit être utilisée pour déterminer le courant en valeur efficace décrit précédemment en S.5.2.4.2.201.

h) Tous les éléments du galvanomètre utilisés doivent être correctement alignés dans l'oscillographe ou les différences de déplacement doivent être notées et utilisées comme cela est exigé.

La sensibilité des galvanomètres et la vitesse d'enregistrement doivent permettre de déterminer avec exactitude les valeurs de tension, de courant et de facteur de puissance. La vitesse d'enregistrement doit être d'au moins 60 in (1,5 m) par seconde.

Le circuit d'essai étant réglé pour fournir les valeurs de tension et de courant spécifiées et avec un shunt (coaxial) non inductif dont il a été déterminé qu'il assure la fonction prévue dans le cadre d'une utilisation en tant que référence connectée dans le circuit, les essais suivants doivent être réalisés pour vérifier l'exactitude des instruments du fabricant.

i) Le secondaire étant mis en court-circuit, le transformateur doit être mis sous tension et la tension aux bornes d'essai être observée pour savoir à quel moment se produit le redressement rendant le circuit inutilisable pour les besoins de l'essai, la tension et le courant n'étant pas sinusoïdaux. Six fermetures aléatoires doivent être réalisées pour démontrer que le flux résiduel dans le noyau de transformateur n'entraîne pas de redressement. Si l'essai est réalisé en fermant le circuit secondaire, cette vérification peut être omise si l'essai n'a pas commencé avant la mise sous tension pendant au moins 2 s du transformateur et qu'un examen de l'équipement d'essai indique qu'une durée plus longue est exigée.

j) Les bornes d'essai étant connectées ensemble au moyen d'une barre en cuivre, un circuit monophasé doit être fermé aussi proche que possible du moment qui génère une onde de courant avec un décalage maximal. Le courant de court-circuit et la tension doivent être enregistrés. La tension primaire doit être enregistrée lorsque la fermeture du primaire est utilisée. Le courant mesuré par le shunt de référence doit être dans les limites de 5 % de celui mesuré à l'aide des instruments du fabricant et il ne doit y avoir aucune variation mesurable de relation de phase entre les traces du même courant. La fermeture commandée ne doit pas être exigée pour les circuits polyphasés.

Si l'exactitude des instruments du fabricant est vérifiée, le shunt coaxial de référence doit être retiré du circuit. Le shunt coaxial de référence ne doit pas être utilisé lors de l'étalonnage final du circuit d'essai ni pendant l'essai des contrôleurs.

S.5.2.4.2.202 Essai de court-circuit et essai de défaillance de *composants* – courants de défaut élevés

Si des modèles à l'intérieur d'une série de *BDM/CDM* sont destinés à être assignés avec des valeurs de courant de défaut élevées en plus des valeurs de courant normalisées exigées par le Tableau 36, ils doivent satisfaire à a) et b) ci-dessous ou à S.5.2.4.2.202.

a) la série *BDM/CDM* utilise un *circuit de protection intégrée contre les courts-circuits* pour la conformité à l'essai de court-circuit, 5.2.4.5 et S.5.2.4.5; et

b) le *circuit de protection intégrée contre les courts-circuits* est utilisé selon S.4.3.2.2.

Un modèle représentatif de ceux destinés à être assignés avec des valeurs de courant de défaut élevées doit être utilisé pour les essais. Ce modèle représentatif doit faire l'objet d'un seul essai de court-circuit de courant de défaut élevé.

Les critères de l'échantillon à soumettre à l'essai d'une série de *BDM/CDM* qui utilise des fusibles pour assurer la conformité à cet essai s'appuient sur la comparaison des caractéristiques assignées du fusible avec celles du redresseur commandé en silicium (RCS) ou du dispositif de sortie du transistor de chaque modèle de la série (les caractéristiques assignées spécifiques à évaluer pour chaque modèle sont les valeurs de I^2t et de I_p).

Il n'est pas exigé que les valeurs de courant de défaut élevées pour lesquelles un *BDM/CDM* peut être soumis à l'essai soient l'une des mêmes valeurs détaillées dans le Tableau 36.

Les exigences de réalisation de l'essai de court-circuit de défaut élevé doivent être conformes à 5.2.4.5, à l'exception des différences suivantes.

c) Pour les *BDM/CDM* assignés à plus de 10 000 A, les fusibles de protection du circuit de dérivation contre les courts-circuits doivent se limiter aux fusibles à haut pouvoir de coupure, de type limiteur de courant (classe CC, CF, G, J, L, R, T, etc.).

d) Pour les *BDM/CDM* assignés à 50 hp (37 kW) ou moins et soumis à l'essai à 10 000 A, les fusibles de protection du circuit de dérivation contre les courts-circuits peuvent être de classe H ou de classe K.

e) Un *BDM/CDM* destiné à être utilisé avec des fusibles de classe RK1 ou de classe RK5 doit être soumis à l'essai avec des fusibles ayant les caractéristiques I^2t et I_p pour les fusibles de classe RK5. Toutes les références aux fusibles de classe R sont destinées aux fusibles moyens avec les caractéristiques d'énergie limitée (I^2t) des fusibles de classe RK5.

f) Pour les contrôleurs non combinés, le disjoncteur à utiliser doit être une unité disponible dans le commerce, à boîtier moulé, présentant les mêmes caractéristiques de durée d'ouverture et sans fonction de limitation de courant.

g) Pour les disjoncteurs équipés de limiteurs de courant fournis avec le contrôleur, le courant coupé limité de crête et le rétablissement I^2t du limiteur de courant ne doivent pas être inférieurs à la valeur maximale établie pour le limiteur de courant destiné à être utilisé avec le contrôleur en essai, lorsque l'essai est réalisé sur un circuit monophasé.

h) Le courant coupé limité de crête et le rétablissement I^2t d'un fusible de classe CC, CF, G, J, L, R ou T ou d'un protecteur de moteur contre les courts-circuits ne doivent pas être inférieurs à la valeur maximale établie pour le fusible (voir la série de normes UL 248 relatives aux fusibles) ou aux caractéristiques assignées du protecteur de moteur contre les courts-circuits destiné à être utilisé avec le contrôleur en essai, lorsque l'essai est réalisé sur un circuit monophasé. Pour un fusible dont les limites I_p et I^2t sont établies pour plusieurs niveaux de courant de court-circuit différents, le fusible d'essai doit avoir au moins les valeurs maximales du courant correspondant au courant de court-circuit admissible marqué du contrôleur.

i) Un limiteur d'essai peut être utilisé en lieu et place des fusibles spécifiés aux points c), d), e), et h) ci-dessus.

Pour obtenir les valeurs exigées spécifiées en h) et i) ci-dessus, un fusible, un limiteur de courant ou un protecteur de moteur contre les courts-circuits plus important que ceux spécifiés pour une utilisation avec le dispositif en essai peut être utilisé ou un fusible d'essai disponible dans le commerce conçu et étalonné pour présenter des caractéristiques I^2t et I_p au moins égales aux limites maximales des caractéristiques assignées du fusible, du limiteur de courant ou du protecteur de moteur contre les courts-circuits. Les caractéristiques de courant coupé limité doivent être déterminées selon les exigences suivantes.

Les fusibles, limiteurs de courant ou protecteurs de moteur contre les courts-circuits utilisés pour les essais doivent provenir d'un lot à partir duquel deux échantillons ont été soumis à l'essai. La valeur de I_p et de I^2t déterminée pour les deux échantillons doit être supérieure ou égale aux valeurs exigées. Ces déterminations doivent être réalisées selon les exigences suivantes.

La Figure S.3 est classique d'oscillogrammes obtenus pendant l'essai du fusible, du limiteur de courant ou des protecteurs de moteur contre les courts-circuits. Elle représente un circuit qui a été ouvert avant que le courant n'atteigne sa première crête principale. Le courant coupé limité de crête I_p doit être déterminé comme cela est indiqué.

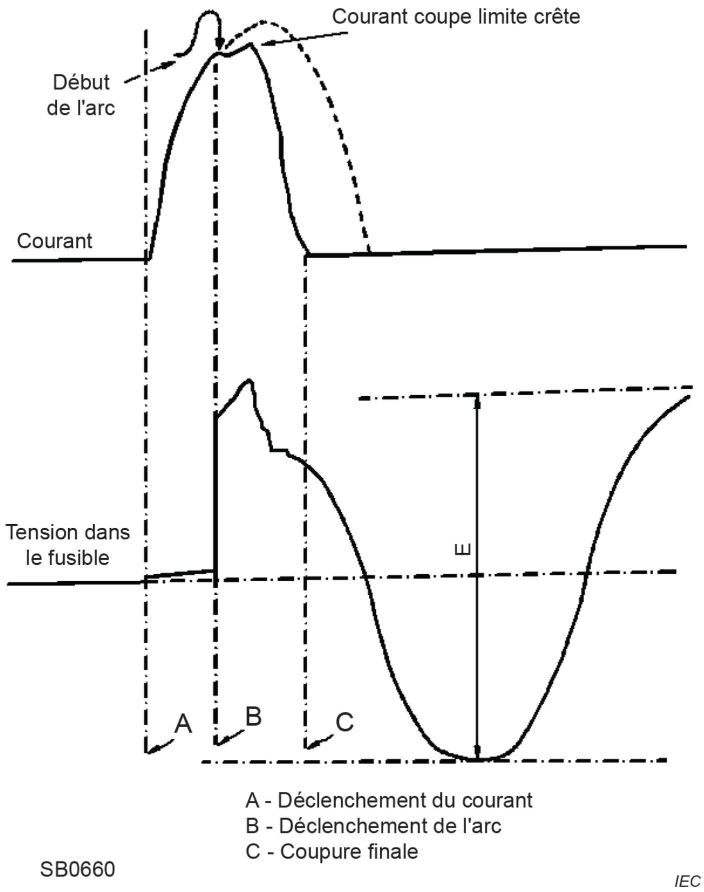


Figure S.3 – Courant coupé limité de crête

L'énergie résiduelle transitoire (I^2t) doit être déterminée à l'aide d'un oscillogramme présentant une trace de courant pendant l'interruption du circuit par le fusible, le limiteur de courant ou le protecteur de moteur contre les courts-circuits. La détermination doit être réalisée par l'application de la règle de Simpson présentée à la Figure S.4 ou à l'aide d'un planimètre d'intégration.

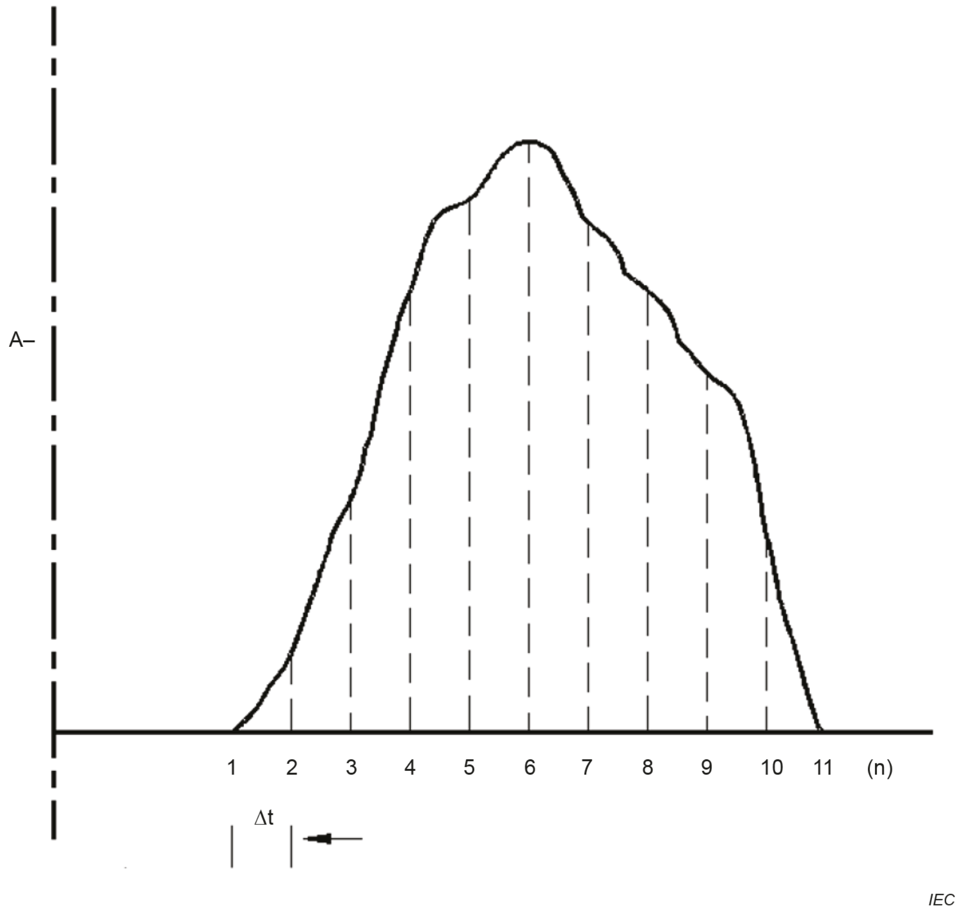


Figure S.4 – Application de la règle de Simpson à l'oscillogramme de courant de fusible pour obtenir le courant coupé limité I^2t

La base de temps en degrés par pouce (degrés/cm) doit être déterminée en moyennant la distance, entre les points de croisement de la ligne de référence de l'onde de tension ou d'une onde de synchronisation, dans laquelle la trace fusible/courant est pratiquement centrée.

S.5.2.4.3 Critères d'acceptation

Ajout à 5.2.4.3:

Il n'est pas exigé de surveiller les tensions des *circuits CTD As* accessibles si le *PDS* satisfait aux exigences tension alternative et de tension continue du 5.2.3.4 à l'issue de l'essai.

S.5.2.4.4 ***Essai de tenue*** **au court-circuit de la** ***liaison*** **équipotentielle** ***de protection*** **(*essai de type*)**

S.5.2.4.5 **Essai de court-circuit en *sortie* (*essai de type*)**

S.5.2.4.6 ***Essai de protection électronique*** **contre les** ***surcharges*** **du** ***moteur*** **(*essai de type*)**

S.5.2.4.6.1 **Exigences générales**

S.5.2.4.6.2 **Montage d'essai**

S.5.2.4.6.3 **Critères d'acceptation**

S.5.2.4.6.4 ***Essai de protection électronique*** **contre les** ***surcharges*** **du** ***moteur*** **(*essai de type*)**

S.5.2.4.6.5 **Essai de *déclenchement électronique de la* rétention de *mémoire* thermique du moteur (*essai de type*)**

S.5.2.4.6.6 **Essai de *perte de rétention* de mémoire thermique électronique du *moteur* (*essai de type*)**

S.5.2.4.6.7 **Essai de sensibilité thermique à la vitesse du moteur électronique (*essai de type*)**

Ajout à 5.2.4.6.7 avec ce qui suit.

En ce qui concerne 5.2.4.6.7, point b) et point e), la fréquence de sortie doit s'appliquer aux *BDM/CDM* avec sortie alternative de puissance de moteur assignée en courant alternatif, et la tension de sortie doit s'appliquer aux *BDM/CDM* avec sortie de puissance de moteur assignée en courant continu.

S.5.2.4.7 **Essai d'évaluation de la fonctionnalité *du* circuit *(essai de type,* essai *individuel de série, essai sur prélèvement*)**

S.5.2.4.8 **Essai de limitation de *courant* (*essai de type*)**

S.5.2.4.9 **Essai de surcharge en *sortie* (*essai de type*)**

S.5.2.4.10 **Essai de *défaillance* de composants *(essai de type*)**

S.5.2.4.11 **Essai de court-circuit des *cartes* de circuit imprimé (*essai de type*)**

Ajout à 5.2.4.11:

L'*enveloppe* extérieure du *PDS* et les parties en métal inerte exposées, en principe destinées à être reliées à la terre, sont déconnectées de la terre et doivent être connectées par un fil en cuivre massif de 10 AWG (5,3 mm²) de 4 ft à 6 ft (1,22 m à 1,83 m) de longueur au pôle du circuit d'alimentation le moins susceptible de présenter un arc à la terre (en règle générale la borne centrale pour les *BDM/CDM/PDS* triphasés).

Si le circuit est interrompu par l'ouverture d'un *composant* autre que le dispositif de protection contre les *surintensités* ou d'une trace de carte de circuit imprimé, l'essai doit être répété pour démontrer des résultats équivalents.

S.5.2.4.12 Essai de perte de phase *(essai de type*)

S.5.2.4.13 Essai de défaillance du *système* de refroidissement (*essai de type*)

S.5.2.4.13.1 Généralités et critères d'acceptation

S.5.2.4.13.2 Essai de moteur de ventilateur *inopérant* (*essai de type*)

Ajout à 5.2.4.13.2:

Si une *condition de premier défaut* électrique peut entraîner la perte de fonctionnement de l'un au moins des ventilateurs, ce défaut est appliqué et la rotation du ventilateur n'est pas empêchée. Cela vient en complément de l'essai consistant à empêcher physiquement la rotation de ventilateurs individuels.

Ajout de paragraphes supplémentaires à 5.2.4:

S.5.2.4.200 Essai de surcharge du contacteur

Un contacteur dont le circuit de bobine est verrouillé ou séquencé de sorte que, dans des conditions normales de fonctionnement, le contacteur n'établisse ni ne coupe le courant de charge, doit être soumis à cinq opérations d'ouverture/fermeture, le verrouillage ou le séquencement étant désactivé. Le courant d'essai doit être le courant que le contacteur transporte lorsque le *BDM/CDM/PDS* délivre le courant de surcharge maximal. Le courant de surcharge maximal est défini comme étant le courant maximal que le *BDM/CDM/PDS* est en mesure de délivrer pendant une durée d'un cycle de fréquence du réseau. La durée de circulation du courant lorsque le contacteur est fermé doit être égale à au moins 4 cycles, et la durée maximale entre les cycles doit être de 240 s. Le facteur de puissance ou la constante de temps pour la charge doit être représentatif de celui/celle du circuit du contacteur en fonctionnement dans le *BDM/CDM/PDS*. La tension du circuit d'essai du contacteur doit être égale à la tension la plus élevée à laquelle le contacteur est soumis pendant le fonctionnement dans le *BDM/CDM/PDS*.

Il ne doit y avoir aucune continuité sur les pôles du contacteur à la fin de la cinquième opération.

À l'issue de l'essai, l'échantillon doit satisfaire aux exigences de l'essai de tension en courant alternatif ou en courant continu du 5.2.3.4.

S.5.2.4.201 *Installation* de groupe (facultatif)

S.5.2.4.201.1 Généralités

Les *BDM/CDM* destinés à une *installation* de groupe doivent satisfaire aux exigences suivantes.

a) Un *BDM/CDM* destiné à être marqué comme état adapté à une *installation* de groupe selon S.6.3.9.6.2 doit être soumis à l'essai selon S.5.2.4.201. Un *BDM/CDM* destiné à une *installation* de groupe à des courants de défaut élevés doit être soumis à l'essai selon S.5.2.4.201.2 à S.5.2.4.201.6. Les bornes de câblage des *BDM/CDM* destinés à une *installation* de groupe doivent satisfaire à S.5.2.4.201.1. Les *BDM/CDM* destinés à une *installation* de groupe selon AA.5.2.4.101.1.2 doivent être marqués selon S.6.3.7.4.1 et le dernier alinéa du S.6.3.7.4.1.
b) Les exigences du S.5.2.4.201 concernent les *BDM/CDM* suivants:
   1) *BDM/CDM* prévus pour une utilisation sur des circuits dont les courants de court-circuit disponibles présentent des niveaux de défaut normalisés ou élevés;
   2) *BDM/CDM* protégés par un disjoncteur à retardement ou un ou plusieurs fusibles non semiconducteurs destinés à assurer la protection du circuit de dérivation pour au moins deux moteurs ou un ou plusieurs moteurs et d'autres charges. Le ou les dispositifs de protection doivent être choisis selon S.5.2.4.201;

3) *BDM/CDM* connectés aux conducteurs du circuit de dérivation dont le courant permanent admissible n'est pas limité à 125 % du courant d'entrée assigné du contrôleur à pleine charge ou à 125 % du courant de sortie assigné du moteur à pleine charge. Les principaux conducteurs de puissance d'entrée et de sortie doivent être dimensionnés selon S.5.2.4.201;

4) *BDM/CDM* qui comportent une protection intégrée contre les surcharges satisfaisant aux exigences du 5.2.4.7 et qui satisfont à l'essai de *protection électronique contre les surcharges du moteur* du 5.2.4.6.4.

c) Les dispositifs de protection du circuit de dérivation doivent être choisis selon S.5.2.4.1.201, avec les ajouts suivants:

1) les dispositifs de protection du circuit de dérivation doivent être soit des disjoncteurs à retardement soit des fusibles non semiconducteurs;

2) Il est admis que le courant nominal du dispositif de protection soit supérieur aux valeurs spécifiées en S.5.2.4.1.201. La dimension maximale du dispositif de protection du circuit de dérivation ne doit pas dépasser la valeur assignée en ampère calculée par la formule suivante:

$$I = (9{,}6 \times A) - (2{,}2 \times FLA)$$

où

I est la valeur assignée en ampère du dispositif de protection;

A est la dimension de fil maximale et est le courant permanent admissible du Tableau S.10 de la dimension de conducteur la plus importante pour laquelle les bornes du dispositif ont été évaluées;

FLA est le FLA minimal du moteur et est le FLA assigné le plus petit (ou FLA équivalent de la caractéristique assignée de cheval-vapeur du Tableau S.29) marqué sur le dispositif.

d) Le câblage d'entrée et de sortie doit être conforme à S.5.2.4.1.202, avec les ajouts suivants:

1) Il est admis que les principaux conducteurs de puissance d'entrée soient plus importants que ceux spécifiés en S.5.2.4.1.202 a);

2) Il est admis que les principaux conducteurs de puissance d'entrée soient plus importants que ceux spécifiés en S.5.2.4.1.202 c).

e) Une borne de câblage doit satisfaire aux exigences de sécurité et de rupture avec le conducteur de dimension maximale admis par le marquage spécifié en S.6.3.7.4.1.

S.5.2.4.201.2 Sélection de l'échantillon

Un échantillon de *BDM/CDM* qui satisfait à tous égards aux exigences du présent document doit faire l'objet des essais spécifiés en S.5.2.4.201.1. Le *BDM/CDM* doit être connecté en série à

a) un ou plusieurs fusibles non semiconducteurs ou à un disjoncteur à retardement présentant les caractéristiques assignées normalisées maximales avec lesquelles le *BDM/CDM* est destiné à être utilisé, et

b) les dimensions maximales des principaux conducteurs de puissance d'entrée et de sortie avec lesquels le *BDM/CDM/PDS* est destiné à être utilisé.

S.5.2.4.201.3 Essai de court-circuit – *Installation de groupe* pour les courants de défaut normalisés

Un *BDM/CDM* dont les valeurs assignées de court-circuit sont aux niveaux spécifiés dans le Tableau 36 doivent satisfaire aux exigences du 5.2.4.5 avec les ajouts suivants.

a) Un contrôleur de *BDM/CDM* qui n'utilise pas uniquement une protection statique contre les courts-circuits doit être soumis à l'essai sur un circuit qui satisfait au facteur de puissance indiqué dans le Tableau S.22. Le circuit doit être étalonné comme cela est indiqué dans Étalonnage des circuits d'essai, S.5.2.4.2.200 ou S.5.2.4.2.201.

b) Le câblage d'entrée et de sortie doit être conforme à S.5.2.4.201.1.

c) Le courant nominal et le type du ou des dispositifs de protection du circuit de dérivation doivent être choisis selon S.5.2.4.201.1.

d) La protection du circuit de dérivation contre les courts-circuits doit être marquée selon S.6.3.9.6.2.

Tableau S.22 – Facteur de puissance des circuits d'essai pour des dispositifs assignés à 600 V ou moins

Courant d'essai, ampères[a]	Facteur de puissance[b]
10 000 ampères maximum	0,70 à 0,80
10 001 à 20 000	0,25 à 0,30
Supérieur à 20 000	0,15 à 0,20

[a] Ampères symétriques en valeur efficace.

[b] Des circuits dont le facteur de puissance est inférieur peuvent être utilisés.

S.5.2.4.201.4 L'essai de court-circuit – *installation* de groupe pour les courants de défaut élevés

Un *BDM/CDM* dont les valeurs assignées de court-circuit en plus des niveaux spécifiés dans le Tableau 36 doivent satisfaire aux exigences du S.5.2.4.2.202 avec les ajouts suivants.

a) La référence S.5.2.4.201.3 est ajoutée à la référence 5.2.4.5 du S.5.2.4.2.202.

b) Le courant nominal maximal du ou des dispositifs de protection du circuit de dérivation doit être choisi selon S.5.2.4.201.1. Le type du ou des dispositifs de protection du circuit de dérivation doit satisfaire à S.5.2.4.201.1.

S.5.2.4.201.5 Essai de défaillance de *composants* – Essai de défaillance de *composants*

Un *BDM/CDM* dont les valeurs assignées de court-circuit sont aux niveaux disponibles normalisés spécifiés dans le Tableau 36 doit être soumis à l'essai du 5.2.4.10, avec les ajouts suivants.

a) Le *BDM/CDM* doit être connecté en série avec les dispositifs de protection du circuit de dérivation sélectionnés selon S.5.2.4.201.1.

b) Le *BDM/CDM* doit être soumis à l'essai avec un fil de longueur maximale de 4 ft (1,2 m) raccordé à chaque borne d'entrée et borne de sortie (si cela est exigé). Pour les *BDM/CDM* sous enveloppe, le câblage d'entrée et le câblage de sortie (si exigé) doivent ensuite être acheminés par un conduit de 10 in à 12 in (250 mm à 305 mm) de longueur installé sur l'*enveloppe*, les extrémités du conduit étant obturées par du coton hydrophile. Pour un *BDM/CDM* de *type ouvert*, une cage grillagée de 1,5 fois la dimension du contrôleur est utilisable pour simuler l'*enveloppe* prévue. La cage grillagée doit être reliée à la terre selon a).

c) Le câblage d'entrée et de sortie doit être conforme à S.5.2.4.201.1.

d) Le *BDM/CDM* doit être soumis à l'essai sur un circuit étalonné comme cela est indiqué en S.5.2.4.2.200. Le courant de court-circuit disponible du circuit d'essai doit être la valeur de courant de défaut normalisée selon le Tableau 36.

S.5.2.4.201.6 Essai de défaillance de *composants* – *Installation* de groupe pour les courants de défaut élevés

Un *BDM/CDM* dont les valeurs assignées de court-circuit sont supérieures aux niveaux spécifiés dans le Tableau 36 doit satisfaire à S.5.2.4.201.5.

Un *BDM/CDM* dont les valeurs assignées de court-circuit sont supérieures aux niveaux spécifiés dans le Tableau 36 doit de plus être soumis à l'essai du 5.2.4.10, avec les ajouts suivants:

a) S.5.2.4.201.5, a) à d), est ajouté aux exigences du 5.2.4.10;
b) les dispositifs de protection du circuit de dérivation doivent également satisfaire à S.5.2.4.2.202, c) à i).

Le *BDM/CDM* doit être soumis à l'essai sur un circuit étalonné comme cela est indiqué en S.5.2.4.2.201. Le courant de court-circuit disponible du circuit d'essai doit être la valeur maximale pour laquelle le *BDM/CDM* est assigné. Il n'est pas exigé que les valeurs de courant de défaut élevées pour lesquelles un *BDM/CDM* peut être soumis à l'essai soient l'une des mêmes valeurs détaillées dans le Tableau 36.

S.5.2.5 Essais de matériaux

S.5.2.6 Essais environnementaux (*essais de type*)

S.5.2.7 Essai de pression hydrostatique *(essai* de *type, essai individuel de série*)

Ajout à 5.2.7:

Pour l'*essai de type*, la pression doit être progressivement augmentée tant que le limiteur de pression ne se déclenche pas ou qu'une valeur égale à 5 fois la pression nominale maximale n'est pas atteinte. Si un limiteur de pression ne se déclenche pas, la pression doit être maintenue à 5 fois la pression nominale maximale pendant 1 min. Il ne doit y avoir aucune fuite de liquide de refroidissement pendant l'essai, autre que celle d'un limiteur de pression pendant un *essai de type*. Aucune fuite du limiteur de pression ne doit se produire dans le compartiment électrique. Après l'*essai de type*, l'essai de tension en courant alternatif ou en courant continu du 5.2.3.4 doit être réalisé.

S.6 Exigences relatives aux informations et au marquage

S.6.1 Généralités

Ajout à 6.1:

Chaque produit fourni, même si plusieurs le sont à un seul client, doit être accompagné de toutes les informations exigées.

L'utilisation de symboles internationaux n'est pas exigée sauf s'ils sont identifiés de manière spécifique.

S.6.2 Informations relatives à la sélection

S.6.2.1 Généralités

Ajout à 6.2.1:

La qualification de type de l'*enveloppe* d'un *BDM/CDM/PDS* doit être clairement marquée pour le *BDM/CDM/PDS* sous enveloppe. Le marquage de classification IP n'est pas exigé.

Avec une référence à S.4.12.201.2, une *enveloppe* de Type 4X destinée à une utilisation intérieure uniquement doit porter le marquage

"Type 4X utilisation intérieure uniquement "

en lettres lisibles et avec la même police et la même hauteur.

Ajout d'un paragraphe supplémentaire à 6.2.1:

S.6.2.1.200 Marquage de circuits de Classe 2

S.6.2.1.200.1 Circuits de Classe 2

Une source de puissance de Classe 2 doit être durablement marquée de manière visible après l'installation afin d'indiquer la classe d'alimentation et sa caractéristique assignée électrique. Une source d'alimentation de Classe 2 n'ayant fait l'objet d'aucune évaluation dans des emplacements humides doit être marquée

" Ne pas utiliser dans des emplacements humides "

ou un équivalent.

Un circuit secondaire destiné à être alimenté par un transformateur ou une source d'alimentation de Classe 2 sur le terrain doit être marqué

" Classe 2" en regard de la tension nominale du dispositif (30 V en courant alternatif, Classe 2, par exemple),

ou un équivalent.

S.6.2.1.200.2 Circuits secondaires

Un circuit secondaire évalué selon les exigences du S.203.1.8 doit être accompagné des instructions d'installation qui spécifient l'utilisation de la source isolée et les caractéristiques assignées des dispositifs de protection contre les *surintensités* exigées pour être installés sur le terrain.

S.6.3 Informations pour l'installation et la mise en service

S.6.3.1 Généralités

Ajout à 6.3.1:

Les marquages exigés dans le présent document doivent inclure la totalité du texte spécifié et peuvent également contenir une représentation graphique. Un texte dans une autre langue que celle spécifiée peut également être prévu.

S.6.3.2 Considérations d'ordre mécanique

S.6.3.3 Environnement

Ajout à 6.3.3:

Les marquages facultatifs suivants doivent uniquement être marqués sur un *BDM/CDM* qui a été évalué selon les exigences d'un *BDM/CDM* à chambre de répartition d'air en S.4.6.200:

- "Peut être installé dans un compartiment à air conditionné"; ou
- " Peut être utilisé dans un autre espace d'environnement conformément à la Section 300.22 (C) du National Electrical Code".

S.6.3.4 Manutention et montage

S.6.3.5 *Température* de l'enveloppe

S.6.3.6 BDM/CDM de *type ouvert*

S.6.3.7 Connexions

S.6.3.7.1 Généralités

S.6.3.7.2 Schémas d'interconnexion et de câblage

Ajout à 6.3.7.2:

Les *BDM/CDM/PDS* intégrant au moins deux circuits séparés pouvant être connectés à des alimentations distinctes et destinés à être connectés à une alimentation commune doivent être marqués

> "Tous les circuits doivent comporter une déconnexion commune et être connectés au même pôle de la déconnexion"

ou une formulation équivalente. Le schéma d'interconnexion du *BDM/CDM/PDS* doit présenter une connexion classique des différents circuits connectés à l'alimentation commune.

S.6.3.7.3 Sélection des conducteurs (câbles)

S.6.3.7.4 Identification et autres précisions relatives *aux bornes pour câblage externe*

S.6.3.7.4.1 Identification des *bornes pour câblage externe*

Ajout à 6.3.7.4.1:

Si des fils sont fournis, le fil destiné à être connecté au circuit d'alimentation relié à la terre doit être de couleur blanche ou grise et doit se distinguer aisément des autres fils.

Une seule borne blanche (autre que le dispositif unipolaire) pour la connexion d'un conducteur non relié à la terre doit être fournie; toutefois, aux moins deux bornes blanches peuvent être prévues:

a) si la manière dont les connexions sont réalisées ne fait aucune différence;
b) si la borne destinée à la connexion du conducteur relié à la terre est évidente; ou
c) les connexions de phase sont toutes indiquées sur un schéma d'interconnexion.

Si un *BDM/CDM/PDS basse tension* ou l'une de ses parties est destiné(e) à être câblé(e) sur le terrain, le *BDM/CDM/PDS* doit satisfaire à ce qui suit.

d) s'il est destiné à ne faire partie que d'un circuit de classe 1, les bornes doivent être marquées en conséquence;
e) s'il est destiné à ne faire partie que d'un circuit de classe 2 câblé avec un fil de Classe 1, les bornes doivent être marquées en conséquence;
f) si le *BDM/CDM/PDS* de coupure ou de consommation de puissance *basse tension* ou une partie du *BDM/CDM/PDS* est destiné(e) à ne devenir qu'une partie d'un circuit de classe 2, les bornes doivent être marquées en conséquence;

g) il n'est pas exigé de marquer un dispositif d'alimentation *basse tension* qui contient un transformateur de manière à indiquer que son usage est acceptable uniquement dans un circuit de classe 2;

h) il n'est pas exigé de marquer un *BDM/CDM/PDS basse tension* ou une partie d'un *BDM/CDM/PDS* destiné(e) à être connecté(e) à un circuit de classe 1 ou à un circuit de classe 2.

Une borne pour câblage qui n'est pas destinée à recevoir un conducteur d'une dimension plus importante que celle spécifiée en S.4.11.11.2 doit être marquée de manière à limiter son usage au conducteur de dimension plus petite.

Une commande avec des caractéristiques assignées du moteur à courant continu qui ne satisfait pas aux exigences du S.4.11.11.2 doit être marquée selon les termes suivants: "AVERTISSEMENT" et ce qui suit, ou un équivalent:

> "Ne pas connecter à un circuit alimenté par un redresseur demi-onde monophasé".

Une commande qui ne satisfait pas aux exigences du S.4.11.11.2 doit être marquée de la manière suivante: "AVERTISSEMENT" et ce qui suit, ou un équivalent:

> "Ne pas connecter à un circuit alimenté par un redresseur monophasé à demi-onde ou à onde entière."

Une *borne pour câblage externe* du *BDM/CDM* destinée à une *installation* de groupe, comme cela est décrit en S.5.2.4.201.1, doit être marquée de manière à limiter son usage aux conducteurs dont la dimension maximale est égale à celle du conducteur soumis à l'essai selon S.5.2.4.201.1.

S.6.3.8 Mise en service

Ajout à 6.3.8:

Ces exigences ne concernent pas les États-Unis, car elles ne sont pas considérées comme faisant partie des spécifications pour la certification.

S.6.3.9 Exigences de protection

S.6.3.9.1 *Parties accessibles* et *circuits*

S.6.3.9.2 Classe de protection

S.6.3.9.3 Circuit de *liaison équipotentielle de protection*

S.6.3.9.4 *Courant de* contact ou courant de fuite élevé

S.6.3.9.5 Compatibilité avec le DDR

S.6.3.9.6 Moyens externes de protection

Remplacement:

S.6.3.9.6.1 Protection du circuit de dérivation contre les courts-circuits

Un *BDM/CDM* doit être marqué

> "Convient aux circuits non susceptibles de délivrer plus de ___________ ampères symétriques eff. maximum ___________ V."

La valeur assignée en ampère ne doit pas être supérieure à la valeur pour laquelle le contrôleur a été soumis à l'essai selon 5.2.4.5 et 5.2.4.10. Si l'essai est conforme à S.5.2.4.2.202, le marquage doit également inclure les éléments suivants (ou un équivalent):

a) "Avec protection par des fusibles de calibre ___________ class fuses," ou
b) " Avec protection par un disjoncteur à pouvoir de coupure nominal d'au moins ___________ ampères symétriques eff. maximum, ___________ Volts."

Un *BDM/CDM* équipé d'une *protection intégrée contre les courts-circuits* selon la *protection intégrée contre les courts-circuits du* S.4.3.2.2 doit être marqué

> "La protection intégrée contre les courts-circuits n'assure pas la protection de la dérivation. La protection du circuit de dérivation doit être exécutée conformément au code national de l'électricité et à tous les codes locaux supplémentaires," ou un équivalent.

Un *BDM/CDM* protégé par des fusibles (à semiconducteurs ou sans semiconducteur), par des disjoncteurs (à retardement ou à *déclenchement* instantané) ou par un contrôleur de moteur combiné de Type E, calibré selon S.5.2.4.1.201 f) à i), k), l), ou n) doit être marqué comme cela est indiqué ci-dessous.

c) Pour les types de fusibles sans semiconducteur, le marquage doit inclure la classe (s'il ne s'agit pas d'une classe H ou d'une classe K5), la tension et le courant ou la tension et le pourcentage du courant nominal de sortie du moteur à pleine charge.
d) Pour les types de fusibles à semiconducteur, le marquage doit indiquer le fabricant et le numéro de modèle du fusible (aucun marquage de caractéristiques assignées du fusible n'est exigé). Ce marquage doit également préciser que le contrôleur de *BDM/CDM* et le dispositif de protection contre les *surintensités* doivent être intégrés dans le même assemblage global.
e) Pour les disjoncteurs limiteurs de courant, le marquage doit inclure la tension et le courant ou la tension et le pourcentage du courant nominal de sortie du moteur à pleine charge. Le marquage doit également indiquer le fabricant et le numéro de modèle du disjoncteur.
f) Pour les types de disjoncteurs à retardement limiteurs de courant, le marquage doit inclure la tension et le courant ou la tension et le pourcentage du courant nominal de sortie du moteur à pleine charge.
g) Pour les types de disjoncteurs à *déclenchement* instantané, le marquage doit indiquer le fabricant et le numéro de modèle du disjoncteur (aucun marquage de caractéristiques assignées du disjoncteur n'est exigé). Ce marquage doit également préciser que le dispositif de protection contre les *surintensités* du *BDM/CDM* doit être intégré dans le même assemblage global.
h) Pour les contrôleurs de moteur combiné de Type E, le marquage doit indiquer le fabricant, le numéro de modèle, la tension assignée et le HP assigné du *BDM/CDM*.

S.6.3.9.6.2 Protection du circuit de dérivation contre les courts-circuits pour une *installation* de groupe

Pour une *installation* de groupe, un *BDM/CDM* selon S.5.2.4.201.1 doit être marqué avec les éléments suivants (ou un équivalent).

a) Si l'essai est réalisé avec des fusibles et des disjoncteurs de la dimension maximale admise: "Convient à une installation de groupe du moteur sur un circuit non susceptible de délivrer plus de ____ ampères symétriques eff. maximum ____ V." Si l'essai est réalisé avec des fusibles autres que ceux de la classe H ou de la classe K5, le marquage doit en outre indiquer: "Avec protection par des fusibles de calibre ___." En cas de valeurs assignées de court-circuit de défaut élevé, le marquage doit en outre indiquer: "Fusibles de calibre ___" ou "Disjoncteur à pouvoir de coupure nominal d'au moins ___ ampères symétriques eff. maximum ___ V."

b) Si l'essai est réalisé uniquement avec des fusibles dont la dimension maximale assignée est celle indiquée en S.5.2.4.201.1 c)2), le marquage doit en outre indiquer: "Avec protection par des fusibles de calibre" ou si l'essai est réalisé avec des fusibles autres que ceux de classe H ou de classe K5, "Avec protection par des fusibles de calibre ___." En cas de valeurs assignées de court-circuit de défaut élevé, "Avec protection par des fusibles de calibre ___."

c) Si l'essai est réalisé avec des dispositifs de protection du circuit de dérivation dont la dimension est inférieure à la dimension maximale assignée indiquée en S.5.2.4.201.1 c)2), le marquage doit en outre indiquer: "avec une protection par (A) de calibre maximal de (B)" où:

   1) (A) le type de dispositif de protection contre les *surintensités*, "des fusibles ou "un disjoncteur". Si l'essai est réalisé avec d'autres fusibles que ceux de la classe H ou de la classe K5, "Fusibles de calibre ___." En cas de valeurs assignées de court-circuit de défaut élevé, "Fusibles de calibre ___" ou "Disjoncteur à pouvoir de coupure nominal d'au moins ___ ampères symétriques eff. maximum ___ V ";

   2) (B) la valeur assignée en ampère maximale du dispositif de protection contre les *surintensités* utilisé pour les essais du S.5.2.4.201.3 et S.5.2.4.201.5, ou S.5.2.4.201.4 et S.5.2.4.201.6.

Un *BDM/CDM* équipé d'une *protection intégrée contre les courts-circuits* selon S.4.3.2.2 et destiné à une *installation* de groupe selon S.5.2.4.201.1 b), doit être marqué selon le deuxième alinéa du S.6.3.9.6.1, ou un équivalent.

S.6.3.9.6.3 Protection du circuit de commande

Le *BDM/CDM/PDS* doit satisfaire aux exigences suivantes pour le marquage relatif à la protection du circuit de commande.

a) Conformément à S.4.11.200.1, p), si la protection supplémentaire du câblage n'est pas exigée en raison des caractéristiques assignées ou du réglage du *déclenchement* d'un disjoncteur à *déclenchement* instantané utilisé comme protection du circuit de dérivation contre les courts-circuits, le *BDM/CDM* doit être accompagné d'un marquage ou d'instructions indiquant la dimension maximale du dispositif de protection du câblage exigée par le Tableau S.13.

b) En ce qui concerne les exigences du S.4.11.200.1, i), si un fusible supplémentaire est utilisé pour assurer la satisfaction à cette exigence, un autre marquage ou d'autres instructions doivent être prévu(es), indiquant la tension et le courant nominaux du fusible.

c) Conformément au troisième alinéa du S.4.11.200.1, si un kit installé sur site est utilisé pour assurer la protection supplémentaire du câblage, le *BDM/CDM* doit être accompagné d'un marquage ou d'instructions permettant d'identifier ce kit.

d) En ce qui concerne l'exigence du quatrième alinéa du S.4.11.200.1, si un fusible (autre qu'un fusible supplémentaire) est utilisé pour assurer la protection supplémentaire du câblage et que le porte-fusible accepte un fusible dont le courant nominal est supérieur à celui exigé en S.4.11.200.1, le *BDM/CDM* doit être accompagné d'un marquage ou d'instructions permettant d'identifier la dimension maximale du fusible.

S.6.3.9.6.4 Courant de défaut disponible élevé – Avertissement contre les dommages

Un *BDM/CDM* destiné à être utilisé sur des circuits dont les courants de défaut disponibles sont élevés, comme cela est indiqué en S.5.2.4.2.202 doit être marqué de la manière suivante: "AVERTISSEMENT", suivi de ce qui suit, ou d’un équivalent:

> "Le déclenchement du dispositif de protection du circuit de dérivation peut être dû à une coupure qui résulte d'un courant de défaut". Pour limiter le risque d'incendie ou de choc électrique, il convient d'examiner les pièces porteuses de courant et les autres *composants* du contrôleur et de les remplacer s'ils sont endommagés. En cas de brûlure de l'élément traversé par le courant dans un relais de surcharge, le relais tout entier doit être remplacé."

S.6.3.9.6.5 Protection du *BDM/CDM/PDS* relié par un cordon contre les *surintensités*

Lorsque cela est exigé par S.4.11.10.1, un *BDM/CDM/PDS* relié par un cordon doit porter un marquage indiquant la tension nominale et la valeur assignée en ampère du dispositif de protection contre les *surintensités* exigé.

Ajout d'un paragraphe supplémentaire à 6.3.9:

S.6.3.9.200 Liaison équipotentielle de l'*enveloppe*

Le marquage exigé pour les *enveloppes* destinées à un assemblage sur le terrain des moyens de liaison équipotentielle selon S.4.4.4.2.200 doit

a) être placé dans un endroit visible pendant l'installation (à l'intérieur du *capot*, par exemple), et

b) être composé du terme "PRUDENCE" suivi, le cas échéant, de:

   - "La liaison équipotentielle entre les connexions du conduit n'est pas automatique et doit être assurée au moment de l'*installation*"; et/ou
   - " Une *enveloppe* non métallique n'assure pas la mise à la terre entre les connexions du conduit. Utiliser des traversées de mise à la terre et des fils de liaison."

Une *enveloppe* de matériau isolant ne comportant aucun moyen permettant d'assurer la continuité de la mise à la terre entre les conduits doit porter un marquage indiquant qu'un seul conduit doit être relié à l'*enveloppe*.

S.6.4 Informations pour l'utilisation

S.6.4.1 Généralités

Ajout à 6.4.1:

Pour les besoins de la certification, l'identification dans le manuel de ces dangers et de ces risques traités de manière spécifique dans le présent document apparaît suffisante.

S.6.5 Informations complémentaires

S.6.5.1 Généralités

Ajout à 6.5.1:

Les *enveloppes* équipées de *capots* amovibles, comme cela est indiqué en S.4.12.201.10.1 e), doivent porter le marquage "AVERTISSEMENT" suivi de:

> "RISQUE DE CHOC ÉLECTRIQUE – Débrancher l'alimentation avant de retirer le capot."

S.6.5.2 Décharge de condensateurs

S.6.5.3 Mode de fonctionnement spécial – Redémarrage automatique/connexion de dérivation

S.6.5.4 Autres dangers

Ajout à 6.5.4:

Un dissipateur thermique actif ou une autre partie prise par erreur pour une partie en métal inerte et auxquelles des personnes ont accès doit porter le marquage "PRUDENCE", suivi de ce qui suit, (ou un équivalent):

> "Risque de choc électrique – Les plaques (ou un autre terme décrivant le type de partie dont il s'agit) sont actives – Débrancher l'alimentation avant de procéder à l'entretien."

Le marquage doit être placé sur la *partie active*.

S.6.5.5 *BDM/CDM/PDS* à plusieurs sources d'alimentation

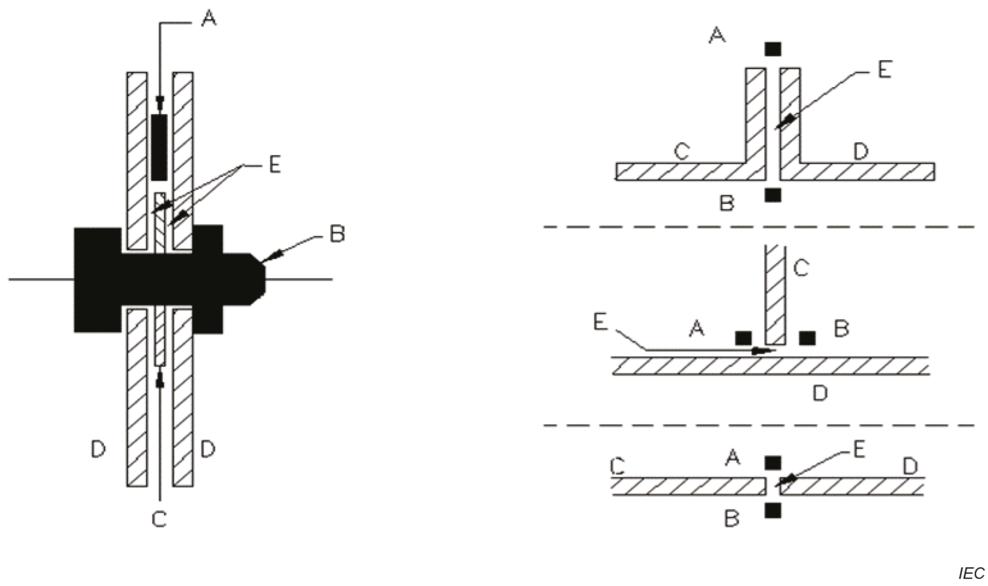
S.6.5.6 Connexion TP/TI

S.6.5.7 Conditions d'accès au *PDS*/*CDM/PDS haute* tension pendant la maintenance

Article supplémentaire:

S.200 Évaluation des distances d’isolement et des *lignes de fuite*

Un joint serré est un joint placé entre deux éléments sous pression de l'*isolation*, comme cela est représenté à la Figure S.5. Les adhésifs, les ciments et les matériaux similaires utilisés pour avoir un impact sur un joint bien serré doivent satisfaire à l'UL 746C. Si la *distance d'isolement* et la *ligne de fuite* entre la partie A et la partie B de la Figure S.5 sont inférieures à celles exigées par 4.4.7.4 et 4.4.7.5 lorsque la mesure est réalisée à travers le joint serré, ce dernier doit satisfaire à l'essai du S.5.2.3.203.



Légende

Tailles A, B *parties actives* de polarité opposée ou *partie active* et partie métallique reliée à la terre avec des *distances d'isolement* et *lignes de fuite* à travers la fissure entre C et D inférieur à ce qui est exigé en 4.4.7.4 et 4.4.7.5

Tailles C, D barrières isolantes fortement serrées ensemble, la rigidité diélectrique entre A et B étant supérieure à la *distance d'isolement* équivalente.

Taille E le joint serré.

Figure S.5 – Joint serré

S.200.1 *Distances d'isolement* et *lignes de fuite*

Le paragraphe S.200.1 donne les exigences en matière de *distances d'isolement* et de *lignes de fuite* au niveau des *bornes pour câblage externe* qui n'excluent pas la possibilité de brins dispersés et en des points d'une *enveloppe* conductrice où des méthodes de câblage peuvent être installées.

Tableau S.23 – *Distances d'isolement* et *lignes de fuite* minimales au niveau des *bornes pour câblage externe* jusqu'à 600 V

Potentiel impliqué en V courant alternatif ou courant continu eff.		*Distances d'isolement* et *lignes de fuite* minimales, pouces (mm)							
		A			B		C		D
		Équipement de commande industriel général			Dispositifs ayant des caractéristiques assignées limitées[a]		Autres dispositifs[b]		Tous les circuits[e]
		51 à 150	151 à 300	301 à 600	51 à 300	301 à 600	51 à 150	151 à 300	0 à 50
Entre une *partie active* non isolée et une *partie active* non isolée de polarité opposée, une partie reliée à la terre non isolée autre que l'*enveloppe* ou une partie métallique exposée[g,h]	*Distance d'isolement*	1/8[c]	1/4	3/8	1/16[c]	3/16[c]	1/8[c]	1/4	1/16[c]
		(3,2)	(6,4)	(9,5)	(1,6)	(4,8)	(3,2)	(6,4)	(1,6)
	Ligne de fuite	1/4	3/8	1/2	1/8[c]	3/8	1/4	1/4	1/16
		(6,4)	(9,5)	(12,7)	(3,2)	(9,5)	(6,4)	(6,4)	(1,6)
Entre une *partie active* non isolée et les parois d'une *enveloppe* métallique, y compris les fixations du conduit ou le câble blindé[d,f]	*Distance d'isolement* et *ligne de fuite*	1/2	1/2	1/2	1/4	1/2	1/4	1/4	1/4
		(12,7)	(12,7)	(12,7)	(6,4)	(12,7)	(6,4)	(6,4)	(6,4)

NOTE 1 Une fente ou une rainure de 0,013 in (0,33 mm) de largeur maximum à proximité du matériau isolant doit être ignorée.

NOTE 2 Un vide d'air de 0,013 pouce (0,33 mm) maximum entre une *partie active* et une surface isolante doit être ignoré lors du mesurage des *lignes de fuite*.

[a] Applicables aux circuits autres que les circuits de moteur dans le *BDM/CDM/PDS*:

a) Mode pilote assigné 720 VA ou moins; ou 15 A maximum à 51 V – 150 V, 10 A maximum à 151 V – 300 V, ou 5 A maximum à 301 V – 600 V.

b) Du type spécifié en (a) qui commande plusieurs charges, à condition que la charge totale reliée à l'alimentation à un moment donné dépasse 1 440 VA ou que son courant nominal soit supérieur à 30 A entre 51 et 150 V, 20 A entre 151 et 300 V ou à 10 A entre 301 et 600 V.

[b] Applicables aux *BDM/CDM/PDS* assignés à 300 V au maximum et 1 hp (sortie de 746 W) au maximum ou 2 000 VA au maximum par pôle et à un dispositif dont le courant nominal par pôle est de 15 A au maximum entre 51 et 150 V et/ou 10 A entre 151 et 300 V.

[c] Les *distances d'isolement* et *lignes de fuite* entre des *bornes pour câblage externe* de polarité opposée et les *distances d'isolement* et *lignes de fuite* entre une *borne pour câblage externe* et une partie en métal inerte reliée à la terre doivent être d'au moins ¼ pouce (6,4 mm) si la mise en court-circuit ou la mise à la terre de ces bornes entraîne la projection de brins de fil. Pour les circuits n'impliquant aucun potentiel supérieur à 50 V eff. en courant alternatif ou en courant continu, les *distances d'isolement* et les *lignes de fuite* au niveau des *bornes pour câblage externe* peuvent être respectivement de 1/8 in (3,2 mm) et de ¼ pouce (6,4 mm).

[d] Dans le cadre de cette exigence, un élément métallique fixé à l'*enveloppe* en fait partie intégrante si la déformation de l'*enveloppe* réduit les *distances d'isolement* et les *lignes de fuite* entre l'élément métallique et les *parties actives* non isolées.

[e] Les *distances d'isolement* et les *lignes de fuite* s'appliquent comme cela est indiqué, sauf, comme cela est spécifié, celles de degré de pollution 2 selon S.200.1 et les *distances d'isolement* et les *lignes de fuite* entre le circuit à faible potentiel satisfont aux exigences applicables au circuit à potentiel élevé.

[f] S'applique aux dispositifs avec des *enveloppes* en tôle quelle que soit l'épaisseur de paroi et aux *enveloppes* en métal coulé dont l'épaisseur de paroi est inférieure à 1/8 pouces (3,2 mm).

[g] Ces *distances d'isolement* et *lignes de fuite* s'appliquent également entre des *parties actives* non isolées et les parois d'une *enveloppe* en métal coulé avec une épaisseur de paroi d'au moins 1/8 pouce (3,2 mm).

[h] Ces *distances d'isolement* et *lignes de fuite* s'appliquent également entre une *partie active* isolée et la paroi d'une *enveloppe* métallique sur laquelle le *composant* est monté. La déformation de l'*enveloppe* ne doit pas réduire les *distances d'isolement* et les *lignes de fuite* ni entraîner un risque de choc électrique.

Tableau S.24 – *Distances d'isolement* et *lignes de fuite* minimales au niveau des *bornes pour câblage externe* supérieures à 600 V

Potentiel concerné, en V	**Emplacement**	***Distances d'isolement* et *lignes de fuite* minimales**, en (mm)			
		601 – 1 000		**1 001 – 1 500**	
Entre une *partie active* non isolée et une *partie active* non isolée de polarité opposée, une partie reliée à la terre non isolée autre que l'*enveloppe* ou une partie métallique exposée	*Distance d'isolement* dans l'air	0,55	(14,0)	0,70	(17,8)
	Distance d'isolement dans l'huile	0,45	(11,4)	0,60	(15,2)
	Ligne de fuite dans l'air	0,85	(21,6)	1,20	(30,5)
	Ligne de fuite dans l'huile	0,62	(15,7)	0,70	(17,8)
Entre une *partie active* non isolée et les parois d'une *enveloppe* métallique, y compris les fixations du conduit ou le câble blindé	*Distance d'isolement* dans l'air ou l'huile	0,80	(20,3)	1,20	(30,5)
	Ligne de fuite	1,00	(25,4)	1,65	(41,9)

Tableau S.25 – *Distances d'isolement* et *lignes de fuite* au niveau des *bornes pour câblage externe* des environnements de degré de pollution 2

Potentiel concerné, V		***Distances d'isolement* et *lignes de fuite* minimales** [a], in (mm)					
		Entre les *bornes pour câblage externe*		**Entre des *bornes pour câblage externe* et d'autres parties non isolées de même polarité**			
Valeur efficace	**Crête**	***Distances d'isolement* et *lignes de fuite***		***Lignes de fuite***		***Distance d'isolement***	
0 à 50	0 à 70,7	1/8	(3,2)	1/8	(3,2)	1/8	(3,2)
51 à 250	72,1 à 353,6	1/4	(6,4)	1/4	(6,4)	1/4	(6,4)
251 à 600	355,0 à 848,5	1/2	(12,7)	1/2	(12,7)	3/8	(9,5)

[a] Ces *distances d'isolement* et *lignes de fuite* s'appliquent à la somme des *distances d'isolement* et *lignes de fuite* concernées, où que la partie en métal inerte isolé soit interposée, sans inclure la distance sur la partie métallique.

Pour les *BDM/CDM/PDS* destinés à être utilisés dans un environnement de degré de pollution 2, les *distances d'isolement* et les *lignes de fuite* au niveau des *bornes pour câblage externe* doivent satisfaire à l'un des points suivants:

a) colonne A, B, C ou D du Tableau S.23, y compris la note de bas de page c ou le Tableau S.24; ou

b) Tableau S.25.

Les *distances d'isolement* et *lignes de fuite* au niveau d'une *borne pour câblage externe* doivent être mesurées avec le fil relié à la borne, comme en service. Le fil relié doit être de la dimension plus importante suivant que ce qui est normalement exigé pour le *BDM/CDM/PDS* lorsque la borne est adaptée à celui-là ou que le *BDM/CDM/PDS* ne fait l'objet d'aucun marquage limitant son utilisation.

S.201 Référence normative et normes de *composants*

US National Electrical Code, ANSI/NFPA 70

Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal, and Energy – UL 61800-5-1

Batteries, Lithium – UL 1642

Capacitors – UL 810

Component Connectors for Use in Data, Signal, Control and Power Applications – UL 1977

Controllers, Programmable – Part 2: Equipment Requirements – UL 61131-2

Cords and Cables, Flexible – UL 62

Electrical Analog Instruments – Panel Board Types – UL 1437

Electrical Equipment, Organic Coatings for Steel Enclosures for Outdoor Use – UL 1332

Electrical Wires, Cables, and Flexible Cords, Reference Standard for – UL 1581

Enclosure for Electrical Equipment, Non-Environmental Considerations – UL 50

Enclosures for Electrical Equipment, Environmental Considerations – UL 50E

Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors – UL 486E

Explosion-Proof and Dust-Ignition-Proof Electrical Equipment for Use in Hazardous (Classified) Locations – UL 1203

Fans, Electric – UL 507

Fire Test for Heat and Visible Smoke Release for Discrete Products and Their Accessories Installed in Air-handling Spaces – UL 2043

Fittings, Conduit, Tubing, and Cable – UL 514B

Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains – UL 60384-14

Fuseholders – Part 1: General Requirements – UL 4248-1

Fuseholders – Part 4: Class CC – UL 4248-4

Fuseholders – Part 5: Class G – UL 4248-5

Fuseholders – Part 6: Class H – UL 4248-6

Fuseholders – Part 8: Class J – UL 4248-8

Fuseholders – Part 9: Class K – UL 4248-9

Fuseholders – Part 11: Type C (Edison Base) and Type S Plug Fuse – UL 4248-11

Fuseholders – Part 12: Class R – UL 4248-12

Fuseholders – Part 15: Class T – UL 4248-15

Fuses, Low-Voltage – Part 12: Class R Fuses – UL 248-12

Fuses, Low-Voltage – Part 1: General Requirements – UL 248-1

Fuses, Low-Voltage – Part 11: Plug Fuses – UL 248-11

Fuses, Low-Voltage – Part 14: Supplemental Fuses – UL 248-14

Gaskets and Seals – UL 157

Ground-Fault Sensing and Relaying Equipment – UL 1053

Industrial Control Equipment – UL 508

Information Technology Equipment Safety – Part 1: General Requirements – UL 60950-1

Insulated Winding Wire, Single- and Muliti-Layer – UL 2353

Insulation Coordination Including Clearances and Creepage Distance for Electrical Equipment – UL 840

Marking and Labeling Systems – UL 969

Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures – UL 489

Rotating Electrical Machines – General Requirements – UL 1004-1

Motors, Impedance Protected – UL 1004-2

Motors, Thermally Protected – UL 1004-3

Electric Generators – UL 1004-4

Motors, Fire Pump – UL 1004-5

Motors, Servo and Stepper – UL 1004-6

Motors, Electronically Protected – UL 1004-7

Motors, Inverter Duty – UL 1004-8

Motors, Overheating Protection for – UL 2111

Optical Isolators –UL 1577

Plastic Materials for Parts in Devices and Appliances, Tests for Flammability of – UL 94

Plugs, Receptacles, and Cable Connectors of the Pin and Sleeve Type – UL 1682

Power Units, Class 2 – UL 1310

Polymeric Materials – Long Term Property Evaluations – UL 746B

Polymeric Materials – Short Term Property Evaluations – UL 746A

Polymeric Materials – Use in Electrical Equipment Evaluations – UL 746C

Power Units Other Than Class 2 – UL 1012

Printed-Wiring Boards – UL 796

Protectors, Supplementary, for Use in Electrical Equipment – UL 1077

Semiconductor Devices, Electrically Isolated – UL 1557

Service Equipment, Reference Standard for – UL 869A

Speed Controls, Solid-State Fans – UL 1917

Surge Protective Devices – UL 1449

Switches, Clock-Operated – UL 917

Switches, Enclosed and Dead-Front – UL 98

Switchgear and Controlgear, Low-Voltage – Part 1: General Rules – UL 60947-1

Switchgear and Controlgear, Low-Voltage – Part 4-1: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters – UL 60947-4-1

Switchgear and Controlgear, Low-Voltage – Part 5-2: Control Circuit Devices and Switching Elements – Proximity Switches – UL 60947-5-2

Systems of Insulating Materials – General – UL 1446

Temperature-Indicating and -Regulating Equipment – UL 8731

Terminal Blocks – UL 1059

Terminals, Electrical Quick-Connect – UL 310

Thermistor-Type Devices – UL 1434

Transformers, Low-Voltage – Part 1: General Requirements – UL 5085-1

Transformers, Low-Voltage – Part 2: General Purpose Transformers – UL 5085-2

Transformers, Low-voltage – Part 3: Class 2 and Class 3 Transformers – UL 5085-3

Transformers, Specialty – UL 506

Wire Connectors – UL 486A-486B

Wires and Cables, Machine Tool – UL 1063

Wires and Cables, Thermoplastic-Insulated – UL 83

S.202 Références normalisées IEC aux États-Unis

Aux États-Unis, les références normatives IEC énumérées dans le Tableau S.26 ne s'appliquent pas.

Tableau S.26 – Références normatives IEC qui ne s'appliquent pas

Titre de la norme IEC	Numéro de la norme IEC
Essais d'environnement – Partie 2-78: essais. Essai Cab: Chaleur humide, essai continu	IEC 60068-2-78:2012
Coordination de l'isolement – Partie 1: Définitions, principes et règles	IEC 60071-1:2019
Codage des dispositifs indicateurs et des organes de commande par couleurs et moyens supplémentaires	IEC 60073:2002
Symboles graphiques utilisables sur le matériel – Partie 2: Dessins originaux	IEC 60417-2:1998, IEC 60417-2:1998/AMD1:2000 et IEC 60417-2:1998/AMD2:2002[6]
Ensembles d'appareillage à basse tension – Partie 1: Ensembles de série et ensembles dérivés de série	IEC 60439-1:1999, IEC 60439-1:1999/AMD1:2004
Principes fondamentaux et de sécurité pour les interfaces homme-machine, le marquage et l'identification – Identification des bornes de matériels, des extrémités de conducteurs et des conducteurs	IEC 60445:2021
Principes fondamentaux et de sécurité pour l'interface homme-machine, le marquage et l'identification – Principes de manœuvre	IEC 60447:2004
Protection contre les chocs électriques – Aspects communs aux installations et aux matériels	IEC 61140:2016
Symboles graphiques pour schémas – Partie 7: Appareillage et dispositifs de commande et de protection	IEC 60617-7:1996
Dispositifs de connexion pour circuits basse tension pour usage domestique et analogue – Partie 1: Règles générales	IEC 60998-1:2002
Compatibilité électromagnétique (CEM) – Partie 4-2: Techniques d'essai et de mesure – Essai d'immunité aux décharges électrostatiques	IEC 61000-4-2:2008
Compatibilité électromagnétique (CEM) – Partie 4-3: Techniques d'essai et de mesure – Essai d'immunité aux champs électromagnétiques rayonnés aux fréquences radioélectriques	IEC 61000-4-3:2020
Compatibilité électromagnétique (CEM) – Partie 4-4: Techniques d'essai et de mesure – Essais d'immunité aux transitoires électriques rapides en salves	IEC 61000-4-4:2012
Compatibilité électromagnétique (CEM) – Partie 4-5: Techniques d'essai et de mesure – Essai d'immunité aux ondes de choc	IEC 61000-4-5:2014, IEC 61000-4-5:2014/ AMD1:2017
Appareils industriels, scientifiques et médicaux – Caractéristiques de perturbations radioélectriques – Limites et méthodes de mesure	CISPR 11:2015/, CISPR 11:2015/AMD1:2016, CISPR 11:2015/AMD2:2019
Compatibilité électromagnétique des équipements multimédia – Exigences d'émission	CISPR 32:2015, CISPR 32:2015/AMD1:2019

[6] Cette publication a été retirée.

Aux États-Unis, les références normatives IEC énumérées dans le Tableau S.27 sont remplacées par la norme américaine indiquée.

Tableau S.27 – Références normatives IEC remplacées par des normes américaines

Titre de la norme IEC	Numéro de la norme IEC	Titre de la norme américaine	Numéro de la norme américaine
Techniques des essais à haute tension	IEC 60060-1:2010	Techniques for High-Voltage Testing	ANSI/IEEE 4
Isolation électrique – Évaluation et désignation thermiques	IEC 60085:2007	Systems of Insulating Materials – General	UL 1446
Parafoudres – Partie 1: Parafoudres à résistance variable avec éclateurs pour réseaux à courant alternatif	IEC 60099-1:1991, IEC 60099-1:1991/AMD1:1999	Metal-Oxide Surge Arrestors for AC Power Circuits	ANSI/IEEE C62.11
		Gapped Silicon-Carbide Surge Arrestors for AC Power Circuits	IEEE C62.1
		Surge Protective Devices	UL 1449
Méthode de détermination des indices de résistance et de tenue au cheminement des matériaux isolants solides	IEC 60112:2020	Polymeric Materials – Short Term Property Evaluations	UL 746A
		Polymeric Materials – Use in Electrical Equipment Evaluations	UL 746C
Matériaux isolants électriques – Propriétés d'endurance thermique – Partie 1: Méthodes de vieillissement et évaluation des résultats d'essai	IEC 60216-1:2013	Polymeric Materials – Long Term Property Evaluations	UL 746B
Fusibles basse tension – Partie 1: Exigences générales	IEC 60269-1:2006, IEC 60269-1/AMD1:2009, IEC 60269-1/AMD2:2014	Low-Voltage Fuses – Part 1: General Requirements	UL 248-1
Fusibles basse tension – Partie 2: Exigences supplémentaires pour les fusibles destinés à être utilisés par des personnes habilitées (fusibles pour usages essentiellement industriels) – Exemples de systèmes de fusibles normalisés A à K	IEC 60269-2:2013, IEC 60269-2:2013/AMD1:2016	Low Voltage Fuses – Part 4: Class CC Fuses	UL 248-4
		Low Voltage Fuses – Part 5: Class G Fuses	UL 248-5
		Low Voltage Fuses – Part 6: Class H Non-Renewable Fuses	UL 248-6
		Low Voltage Fuses – Part 7: Class H Renewable Fuses	UL 248-7
		Low Voltage Fuses – Part 8: Class J Fuses	UL 248-8
		Low Voltage Fuses – Part 9: Class K Fuses	UL 248-9
		Low Voltage Fuses – Part 10: Class L Fuses	UL 248-10
		Low Voltage Fuses – Part 11: Plug Fuses	UL 248-11
		Low Voltage Fuses – Part 12: Class R Fuses	UL 248-12
		Low Voltage Fuses – Part 13: Semiconductor Fuses	UL 248-13
		Low Voltage Fuses – Part 14: Supplemental Fuses	UL 248-14
		Low Voltage Fuses – Part 15: Class T Fuses	UL 248-15

Titre de la norme IEC	**Numéro de la norme IEC**	**Titre de la norme américaine**	**Numéro de la norme américaine**
		Low-Voltage Fuses – Part 17: Class CF Fuses	UL 248-17
Installations électriques à basse tension – Partie 4-44: Protection pour assurer la sécurité – Protection contre les perturbations de tension et les perturbations électromagnétiques	IEC 60364-4-44:2007, IEC 60364-4-44:2007/AMD1:2015, IEC 60364-4-44:2007/AMD2:2018	US National Electrical Code	ANSI/NFPA 70
Coordination de l'isolement des matériels dans les systèmes (réseaux) à basse tension – Partie 1: Principes, prescriptions et essais	IEC 60664-1:2020	Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment	UL 840
Essais relatifs aux risques du feu – Partie 2-10: Essais au fil incandescent/chauffant – Appareillage et méthode commune d'essai	IEC 60695-2-10:2021	Polymeric Materials – Use in Electrical Equipment Evaluations	UL 746C
Essais relatifs aux risques du feu – Partie 2-11: Essais au fil incandescent/chauffant – Méthode d'essai d'inflammabilité pour produits finis (GWEPT)	IEC 60695-2-11:2021	Polymeric Materials – Use in Electrical Equipment Evaluations	UL 746C
Essais relatifs aux risques du feu – Partie 2-12: Essais au fil incandescent/chauffant – Méthode d'essai d'indice d'inflammabilité au fil incandescent (GWFI) pour matériaux	IEC 60695-2-12:2021	Polymeric Materials – Use in Electrical Equipment Evaluations	UL 746C
Essais relatifs aux risques du feu – Partie 2-13: Essais au fil incandescent/chauffant – Méthode d'essai de température d'allumage au fil incandescent (GWIT) pour matériaux	IEC 60695-2-13:2021	Polymeric Materials – Use in Electrical Equipment Evaluations	UL 746C
Essais relatifs aux risques du feu – Partie 11-5: Flammes d'essai – Méthode d'essai au brûleur-aiguille – Appareillage, dispositif d'essai de vérification et lignes directrices	IEC 60695-11-5:2016	Polymeric Materials – Use in Electrical Equipment Evaluations	UL 746C
Essais relatifs aux risques du feu – Partie 11-20: Flammes d'essai – Méthode d'essai à la flamme de 500 W	IEC 60695-11-20:2015	Test for Flammability of Plastic Materials for Parts in Devices and Appliances	UL 94
Appareillage à basse tension – Partie 5-1: Appareils et éléments de commutation pour circuits de commande – Appareil électromécaniques pour circuits de commande	IEC 60947-5-1:2016	Low-voltage switchgear and controlgear – Part 5-1: *Control circuit* devices and switching elements – Electromechanical *control circuit* devices	UL 60947-5-1
Extra heavy-duty electrical rigid steel conduits (disponible en anglais seulement)	IEC 60981:2019	Electrical Rigid Metal Conduit – Steel	UL 6

S.203 Circuits secondaires isolés et circuits alimentés par batterie

S.203.1 Circuits secondaires isolés

S.203.1.1 Généralités

Un circuit secondaire isolé est un *circuit de commande* qui est totalement isolé du circuit de dérivation primaire. Cette *isolation* doit être assurée au moyen d'un transformateur, d'un isolateur optique, d'une impédance de limitation ou d'un relais électromécanique.

Un circuit secondaire isolé doit satisfaire aux conditions suivantes:

1) séparation des circuits, S.203.1.1;
2) essai de tension en courant alternatif ou en courant continu du 5.2.3.4;
3) les exigences applicables pour l'un des types suivants de circuits secondaires isolés:
   a) un circuit de Classe 2, voir S.203.1.5 et le Tableau S.28;
   b) un circuit à tension/courant limité, voir S.203.1.6 et le Tableau S.28;
   c) un circuit à énergie limitée, voir S.203.1.7 et le Tableau S.28;
   d) un circuit à impédance de limitation, voir S.203.1.8 et le Tableau S.28;
   e) un circuit à tension limitée, voir S.203.1.9 et le Tableau S.28;
   f) un circuit à alimentation isolée, voir S.203.1.10 et le Tableau S.28.

Tableau S.28 – Circuits secondaires, différences dans l'évaluation

Article		Type de circuit secondaire isolé								
		Class 2	Tension/ courant limité	Énergie limitée		Impédance limitée			Tension limitée	Alimentation isolée
S.203.1.3	Risque de choc électrique dans le circuit?	Non	Non	Non	Oui	Non	Non	Oui	Non	Oui
S.203.1.4	Risque de danger thermique dans le circuit?	Non	Non	Oui	Oui	Non	Non	Non	Oui	Oui
Caractéristiques électriques de la source secondaire isolée (ISC)										
S.203.1.5 à S.203.1.10	Tension maximale, courant alternatif	[b]	30	30	100	-	30	-	30	150
	Tension maximale, crête	[b]	42,4	42,4	-	-	42,4	-	42,4	-
	Courant secondaire maximal, A	[b]	8	-	-	0,005[a]	-	-	-	-
	Puissance secondaire maximale, VA	[b]	100	200	200	15 W	15 W	15 W	-	10 k
Exigences de *composants* à l'intérieur du circuit secondaire isolé (ICS)										
4.4.7	Cartes de circuit imprimé	-	-	[c]	[c]	-	-	-	[c]	x

Article		**Type de circuit secondaire isolé**								
		Class 2	**Tension/ courant limité**	**Énergie limitée**		**Impédance limitée**			**Tension limitée**	**Alimentation isolée**
4.11	Câblage interne	-	-	x	x	-	-	-	x	x
	Tous les autres *composants*	[d]	[d]	[d]	[d]	[d]	[d]	[d]	[d]	[d]
Exigences de distances d'isolement et de *lignes de fuite* du circuit secondaire isolé (ICS)										
4.4	À l'intérieur de l'ISC	-	-	-	-	-	-	-	-	-
	Entre l'ISC et la terre	-	-	-	x	-	[e]	x	-	[e]
	Entre l'ISC et l'enveloppe ou les parties accessibles	-	-	-	x	-	[e]	x	-	[e]
	Entre l'ISC et d'autres circuits isolés	x	x	x	x	x	x	x	x	x
Protection contre le contact direct										
4.4	L'ISC exige une protection contre le contact direct	-	-	x	x	-	-	x	x	x
Exigences de performances										
Source isolée (telle que: Transformateur, alimentation, Impédance de limitation, batterie):										
S.203.1	Circuit secondaire	[b]	S.203.2.2	S.203.2.3	S.203.2.3	S.203.2.4	S.203.2.4	S.203.2.4	S.203.2.5	S.203.2.6
5.2.6.3.2	Température	[d]	[d]	[d]	[d]	[d]	[d]	[d]	[d]	[d]
5.2.4.10	Défaillance de *composants*	[b]	x	x	x	x	x	x	x	x
NOTE "x" indique les exigences qui s'appliquent, alors que " – " indique les exigences qui ne s'appliquent pas.										

[a] Voir S.203.1.2 b).

[b] Voir l'UL 1310 ou l'UL 5085-1, et l'UL 5085-3, pour connaître les caractéristiques électriques maximales et les exigences de performances.

[c] Les cartes de circuit imprimé doivent satisfaire à l'UL 796, et doivent être assignées V-2, V-1 ou V-0.

[d] Aucune évaluation exigée, à l'exception des effets des *composants* générant de la chaleur dans le circuit secondaire isolé sur les *composants* adjacents (les cartes de circuit imprimé et le câblage, par exemple) qui doivent être évalués pendant l'essai de température.

[e] Voir S.203.1.10.

[f] Les essais spécifiés dans le présent tableau permettent d'évaluer les *composants* d'isolation utilisés avec les circuits secondaires. Il n'indique pas tous les essais applicables aux *composants* d'isolation.

S.203.1.2 Séparation des circuits

Les circuits secondaires isolés installés en usine doivent être séparés de tous les autres circuits conformément à l'alinéa suivant. Les conducteurs isolés doivent être séparés du câblage et des *parties actives* non isolées reliées à d'autres circuits. Le câblage et les *composants* fournis avec l'*isolation* et assignés pour la tension la plus élevée sont considérés comme étant séparés les uns des autres.

La séparation des conducteurs isolés doit être réalisée par serrage, par acheminement ou par des moyens équivalents qui assurent la séparation permanente des *parties actives* isolées ou non isolées d'un circuit différent.

Une barrière permanente doit être prévue pour séparer les conducteurs de classe 2 des circuits secondaires installés sur le terrain de tous les autres circuits.

Une barrière permanente n'est pas exigée si des conducteurs de classe 1 ou des conducteurs de puissance sont simplement introduits pour la connexion au *BDM/CDM/PDS* relié à un circuit de classe 2 et

a) des dispositions ont été prises pour acheminer des conducteurs de classe 1 ou des conducteurs de circuit de puissance afin de maintenir une séparation minimale de 1/4 pouces (6,35 mm) par rapport aux conducteurs du circuit de classe 2, ou
b) les conducteurs de Classe 1 ou les conducteurs de circuit de puissance fonctionnent à 150 V au maximum à la terre et satisfont également à l'un des éléments suivants:
    1) des dispositions ont été prises pour permettre l'installation de circuits de classe 2 à l'aide de câbles de types CL3, CL3R, CL3P, ou équivalents, et les conducteurs de câble qui s'étendent au-delà du conteneur peuvent être séparés de tous les autres conducteurs par au moins 1/4 pouces (6,35 mm), par un manchon non conducteur ou par une barrière non conductrice; ou
    2) il est exigé d'installer les conducteurs de classe 2 en tant que circuit de classe 1 conformément à la Section 725-21 du National Electrical Code, ANSI/NFPA 70.

Une barrière permanente n'est pas exigée pour les *enveloppes* pour lesquelles une seule ouverture est prévue, si les instructions d'installation stipulent que les conducteurs des circuits de classe 2 doivent être séparés des conducteurs des circuits de classe 1 ou des circuits de puissance par un non-conducteur continu et bien fixé (un tuyau souple, par exemple).

Si aucune barrière permanente n'est prévue, les instructions d'installation doivent être fournies pour expliquer les méthodes de câblage afin de satisfaire aux exigences du S.203.1.2.

Les conducteurs installés sur le terrain et en usine d'au moins deux circuits de classe 2 doivent être acheminés à l'intérieur du même câble, de la même *enveloppe* ou du même chemin de câbles.

S.203.1.3 Risque de choc électrique

Il existe un risque de choc électrique à l'intérieur d'un circuit, sauf si ledit circuit satisfait à l'un des critères suivants:

a) le circuit est alimenté par une source isolée telle que le potentiel de tension maximal du circuit ouvert dont dispose le circuit ne dépasse pas 30 V en courant alternatif ou 42,4 V crête; ou
b) le circuit est alimenté par une source isolée de sorte que le courant disponible à travers une résistance de 1 500 Ωhm par un potentiel du circuit (y compris la terre) ne dépasse pas 5 mA.

S.203.1.4 Risque de danger thermique

Il existe un risque de danger thermique à l'intérieur d'un circuit, sauf si ledit circuit satisfait à l'un des critères suivants:

a) le circuit est alimenté par une source isolée telle que le potentiel de tension maximal du circuit ouvert dont dispose le circuit ne dépasse pas 30 V en courant alternatif ou 42,4 V crête, et que le courant disponible est limité à une valeur qui ne dépasse pas 8 A mesurée après 1 min de fonctionnement; ou
b) le circuit est alimenté par une source isolée de sorte que la puissance dont dispose le circuit est limitée à une valeur inférieure à 15 W.

S.203.1.5 Circuits de Classe 2

Un circuit de Classe 2 doit être alimenté par une source isolée qui satisfait aux exigences de l'UL 1310 ou de l'UL 5085-1 et l'UL 5085-3.

S.203.1.6 Exigences du circuit à tension/courant limité

Un circuit à tension/courant limité doit être alimenté par une source isolée telle que le potentiel de tension maximal du circuit ouvert dont dispose le circuit ne dépasse pas 30 V en courant alternatif ou 42,4 V crête, et que le courant disponible est limité à une valeur qui ne dépasse pas 8 A mesurée après 1 min de fonctionnement dans toutes les conditions de charge afin d'obtenir le courant maximal.

Une alimentation isolante ou un transformateur de type isolant, soumis à l'essai selon S.203.2.2, peut être utilisé pour satisfaire à cette exigence. Un dispositif destiné à être alimenté par une source isolée qui satisfait à cette exigence et à être alimenté comme un *accessoire* sur le terrain doit être marqué selon 6.2.2.

Un fusible secondaire ou un autre dispositif de protection du circuit secondaire utilisé avec une source isolée pour limiter le courant disponible selon le premier alinéa doit être assigné à cinq ampères au maximum pour des tensions secondaires inférieures ou égales à 20 V crête ou 100 VA pour des tensions secondaires supérieures à 20 V et inférieures à 30 V crête, où V est la tension de crête du circuit ouvert.

Si un fusible secondaire conforme à l'alinéa ci-dessus et à la série de normes UL 248 est utilisé, l'essai spécifié en S.203.2.2 n'est pas exigé. Lorsque ce fusible et la source isolée sont destinés à être alimentés sur le terrain, le *BDM/CDM/PDS* doit être accompagné des instructions d'installation selon S.6.2.1.200.2.

Des dispositifs de protection autres que ceux décrits à l'alinéa ci-dessus et des dispositifs de protection présentant des caractéristiques assignées supérieures à celles indiquées en S.203.1.6 peuvent être utilisés si la combinaison source isolée/dispositif de protection est évaluée conformément à S.203.2.2. Si le dispositif de protection et la source isolée sont destinés à être alimentés sur le terrain, le *BDM/CDM/PDS* doit être accompagné des instructions ou des marquages exigés en 6.3.2.

Le dispositif de protection du circuit secondaire peut être fourni dans le circuit primaire. S'il est fourni dans le circuit primaire, le courant nominal du dispositif de protection ne fait l'objet d'aucune restriction tant que ce dernier limite le courant secondaire disponible conformément à S.203.1.6.

Si un dispositif de protection est utilisé, il doit satisfaire aux exigences du présent document et doit être accompagné d'un marquage de remplacement adjacent conformément à S.6.3.9.6.1 ou d'instructions de remplacement qui indiquent la tension nominale et le courant nominal exigés. La carte de circuit imprimé, le câblage et les *distances d'isolement* et *lignes de fuite* qui précèdent le point auquel la tension et le courant sont limités doivent satisfaire aux exigences du circuit primaire du présent document.

Une impédance fixe (un *composant* ou un groupe de *composants* dans le même circuit, par exemple) ou un réseau de réglage (celui utilisé dans une alimentation à commutation, par exemple) utilisé pour limiter la tension et/ou le courant disponible doit être en mesure de fonctionner dans les *conditions de premier défaut* du *composant* selon 4.2.

S.203.1.7 Exigences relatives au circuit à énergie limitée

Un circuit à énergie limitée doit être alimenté par une source isolée telle que la capacité volt-ampère maximale dont dispose le circuit soit de 200 VA à un potentiel de tension maximal en circuit ouvert de 100 V en courant alternatif. La source isolée doit satisfaire à l'essai décrit en S.203.2.3. Un dispositif (circuit) destiné à être alimenté par une source isolée qui satisfait à cette exigence et à être alimenté comme un kit sur le terrain doit être marqué selon 6.2.2.

Un fusible de circuit primaire ou secondaire ou un autre dispositif de protection du circuit de ce type peut être utilisé pour limiter la capacité volt-ampère maximale disponible. Le courant nominal du dispositif de protection ne fait l'objet d'aucune restriction tant que ce dernier maîtrise la limite volt-ampère disponible conformément à S.203.1.7. Le dispositif de protection doit satisfaire aux exigences du présent document et doit faire l'objet d'un marquage conformément à S.6.3.9.6.1.

S.203.1.8 Exigences relatives au circuit à impédance de limitation

Un circuit à impédance de limitation utilisé pour réduire le risque de danger thermique défini en S.203.2.4 doit être alimenté par une impédance qui satisfait à l'un des éléments suivants:

a) la dissipation de puissance calculée de l'impédance, en résultat d'un court-circuit direct appliqué sur le circuit limité par l'impédance, ne dépasse pas la puissance nominale de l'impédance et la limitation de puissance est inférieure à 15 W; ou
b) l'impédance
    1) doit être assignée de sorte que la dissipation de puissance calculée de l'impédance, en résultat d'un court-circuit direct appliqué sur le circuit limité par l'impédance, dépasse la puissance nominale de l'impédance et soit toujours inférieure à 15 W; et
    2) ne doit pas être ouverte ou mise en court-circuit lorsqu'elle est soumise aux effets d'un court-circuit direct appliqué sur le circuit limité par l'impédance comme cela est décrit en S.203.2.4.

La limitation de puissance de 15 W de l'impédance ne doit pas être dépassée dans les *conditions de premier défaut* du *composant*.

Si le circuit limité par l'impédance de 15 W est totalement sous enveloppe sans ouverture de ventilation, les effets des *conditions de premier défaut* du *composant* ne sont pas évalués.

Une impédance de limitation utilisée pour réduire le risque de choc électrique comme cela est défini en S.203.1.3 doit satisfaire à l'un des éléments suivants.

a) L'impédance de limitation est reliée du côté du potentiel élevé d'un diviseur de tension sur une tension d'alimentation monophasée reliée à la terre et assignée à 150 V au maximum. Elle permet de limiter la tension à l'intérieur du circuit secondaire isolé à moins de 30 V en valeur efficace ou de 42,4 V crête à l'intérieur du circuit secondaire, et également par rapport à la terre selon l'analyse du circuit.
b) L'impédance de limitation est reliée à chacune des deux lignes de tension d'alimentation non reliées à la terre à partir d'une alimentation 120/240 V ou à deux ou trois lignes de tension d'alimentation non reliées à la terre à partir d'une alimentation triphasée. Elle permet de limiter la tension à l'intérieur du circuit secondaire isolé à moins de 30 V en valeur efficace ou 42,4 V crête à l'intérieur du circuit secondaire isolé, et également par rapport à la terre selon l'analyse du circuit. Le circuit doit être évalué pour déterminer la tension par rapport à la terre lorsqu'il est relié à un système de tension primaire qui alimente le *BDM/CDM/PDS*.

c) Un circuit secondaire alimenté par un circuit à impédance de limitation est isolé ou comporte des *distances d'isolement* et *lignes de fuite* par rapport aux parties métalliques ou aux *parties accessibles* reliées à la terre et ne comporte pas de câblage externe ou comporte des câblages externes si les deux conditions suivantes sont satisfaites:

   1) le *BDM/CDM/PDS* fait l'objet d'un marquage indiquant la tension maximale par rapport à la terre qui peut être présente sur les câblages externes provenant du circuit secondaire;

   2) le circuit satisfait à l'essai du S.203.2.4 réalisé entre chacune des *bornes pour câblage externe* du circuit à impédance de limitation par rapport à la terre.

Si une impédance de limitation est utilisée pour réduire le risque de choc électrique (S.203.1.3), aucun élément individuel ne doit être confronté à un facteur de contrainte électrique

d) plus de 0,5 fois pendant toutes les conditions normales de fonctionnement, ou

e) plus de 1,0 fois après la défaillance d'un seul *composant* eut égard à la tension, au courant et à puissance dissipée assignés.

Le facteur de contrainte électrique est défini comme étant le rapport de la caractéristique électrique appliquée sur la caractéristique électrique assignée, tel que le rapport entre le courant appliqué et le courant permanent admissible assigné d'un *composant*.

S.203.1.9 Circuits à tension limitée

Un circuit à tension limitée doit être alimenté par une source isolée qui satisfait aux conditions suivantes.

a) Le potentiel de tension maximal en circuit ouvert dont dispose le circuit ne doit pas être supérieur à 30 V en courant alternatif ou à 42,4 V crête sans limitation sur la capacité de courant ou volt-ampère disponible.

b) Tous les câbles d'interconnexion de circuit secondaire externe et tout le câblage de circuit secondaire entre les unités doivent être protégés contre les brûlures et les dommages dont fait l'objet l'*isolation* résultant d'une condition de surcharge ou de court-circuit qui peut se produire pendant l'utilisation du *BDM/CDM/PDS*. Un dispositif de protection contre les *surintensités* doit être prévu et doit satisfaire au Tableau S.13, ou le circuit secondaire isolé doit satisfaire à l'essai de circuit secondaire du S.203.2.5. La protection contre les *surintensités* prévue dans le circuit primaire de la source isolée peut servir de protection pour le circuit secondaire s'il satisfait à S.4.4.6.201.2 ou à l'essai du circuit secondaire du S.203.2.5.

c) La source isolée est destinée à être utilisés dans un environnement de degré de pollution 2.

Si le dispositif de protection, qui satisfait au Tableau S.13, et la source isolée sont destinés à être alimentés sur le terrain, le dispositif doit faire l'objet d'un marquage conformément à S.6.2.1.200.2.

Si le dispositif de protection et la source isolée, qui se sont révélés conformes à S.203.2.5, sont destinés à être alimentés sur le terrain, le dispositif doit faire l'objet d'un marquage conformément à 6.2.2.

S.203.1.10 Circuits à alimentation isolée

Un circuit à alimentation isolée doit être alimenté par le secondaire d'une source isolée conforme à S.203.2.6.

Un circuit à alimentation isolée doit limiter la surtension transitoire dans le secondaire à 300 V crête au maximum lorsque les bornes d'entrée du *BDM/CDM/PDS* sont soumises à une seule impulsion de choc de 1,2/50 µs avec une valeur de crête de 5 kV à l'aide d'un générateur d'essai présentant une impédance interne effective de 12 Ω. Toutes les bornes d'entrée de puissance doivent être connectées ensemble et l'impulsion doit être appliquée entre cette connexion et la terre. Le *BDM/CDM/PDS* doit être opérant à la fin de l'essai.

Pour les circuits assignés à plus de 50 V, les *distances d'isolement* et *lignes de fuite* ne doivent pas être inférieures à 1/8 pouces (3,2 mm) entre les *parties actives* du circuit secondaire et le métal accessible par l'opérateur ou le métal inerte relié à la terre, y compris l'*enveloppe*. Pour les circuits secondaires assignés à 50 volts au maximum, ces *distances d'isolement* et *lignes de fuite* ne doivent pas être inférieures à 1/16 pouce (1,6 mm).

Si les *distances d'isolement* et *lignes de fuite* sont inférieurs à 1/8 pouce (3,2 mm), la construction doit résister, sans claquage ni fuite sur un isolateur, à l'application d'un potentiel en courant alternatif égal à deux fois la tension assignée plus 1 000 V (ou à un potentiel en courant continu égal à 1,4 fois la somme de deux fois la tension assignée plus 1 000 V) pendant 60 s entre le secondaire et les *parties accessibles* ou les parties métalliques non porteuses de courant reliées à la terre. Pendant l'essai, un *composant* normalement relié à la terre doit être déconnecté.

S.203.2 Essai des circuits secondaires

S.203.2.1 Généralités

Sauf spécification contraire, les mesurages d'essai doivent être réalisés comme suit.

a) La tension primaire fournie à la source isolée ne doit pas être inférieure à la tension opérationnelle appliquée au primaire lorsque le *BDM/CDM/PDS* est alimenté à la tension assignée maximale, tolérance positive publiée incluse, mais pas à moins de la valeur spécifiée en S.5.1.5. Pour une source isolée avec plusieurs caractéristiques assignées de tension primaire, la tension nominale la plus élevée doit être utilisée pour cet essai. Les dispositifs de protection contre les *surintensités* ne doivent pas s'ouvrir à l'issue de cet essai.
b) Le potentiel de tension maximal en circuit ouvert dont dispose le circuit secondaire à l'étude doit être mesuré directement sur les bornes de sortie de la source isolée.
c) Pour une source isolée avec plusieurs circuits secondaires, un seul circuit secondaire à la fois doit être soumis à l'essai. Il n'est pas exigé de connecter à une charge tous les secondaires non soumis à l'essai.
d) La tension, le courant et la capacité volt-ampère applicables doivent être mesurés directement sur les bornes de sortie secondaires de la source isolée. Si un enroulement de transformateur à gradins est utilisé pour alimenter un redresseur d'onde complète, les mesurages doivent être réalisés entre l'une des extrémités de l'enroulement et la prise. Si le transformateur est utilisé comme partie intégrante d'une l'alimentation à commutation, les mesurages doivent être réalisés après les dispositifs de redressement de l'enroulement secondaire du transformateur.

S.203.2.2 Essai du secondaire à tension/courant limité

La source isolée étant connectée comme cela est indiqué en S.203.2.1, la tension en circuit ouvert de chaque secondaire ne doit pas dépasser 30 V en valeur efficace ou 42,4 V crête, et le courant disponible dans le secondaire ne doit pas dépasser 8 A après 1 min.

Le courant dont dispose le circuit secondaire en cours d'évaluation doit être mesuré en connectant une charge résistive variable à la source de ce secondaire, puis en surveillant et réglant en permanence la charge selon le cas, de manière à maintenir un courant secondaire légèrement supérieur à 8 A pendant un intervalle d'essai de 1 min. Si un courant disponible supérieur à 8 A ne peut pas être obtenu dans les conditions de charge, jusqu'à un court-circuit inclus, l'essai doit être interrompu pour ce circuit.

S.203.2.3 Essai du secondaire à énergie limitée

La source isolée étant connectée selon S.203.2.1, la tension en circuit ouvert du secondaire ne doit pas dépasser 100 V, et la capacité volt-ampère calculée ne doit pas dépasser 200 VA.

La capacité volt-ampère maximale dont dispose le circuit secondaire à l'étude doit être mesurée en connectant une charge résistive variable sur la source de ce secondaire, puis en mesurant la tension et le courant en faisant passer de manière linéaire la charge résistive du circuit ouvert au court-circuit pendant au moins 1,5 min et 2,5 min au maximum. La capacité volt-ampère disponible maximale est calculée en multipliant les valeurs mesurées simultanément de la tension secondaire et du courant secondaire. Les valeurs mesurées doivent être obtenues au moins une fois toutes les 0,5 s. Il est admis qu'un dispositif de protection contre les *surintensités* fonctionne avant de réduire la charge résistive pour simuler les conditions de court-circuit. Si le dispositif de protection contre les *surintensités* fonctionne avant 1,5 min, les volts-ampères doivent également être calculés avec le circuit secondaire chargé de sorte que le courant qui traverse le dispositif de protection contre les *surintensités* soit égal à sa *surintensité* nominale.

S.203.2.4 Essai d'impédance de limitation anormale

L’essai suivant s’applique aux impédances de limitation utilisées pour réduire le risque de danger thermique comme cela est décrit en S.203.1.8. La source isolée étant connectée selon S.203.2.1, une impédance de limitation ne doit pas émettre de métal en fusion ou de flammes ni enflammer un coton placé sur toutes les ouvertures de ventilation du *BDM/CDM/PDS* ou totalement autour du *BDM/CDM/PDS de type ouvert* lorsque le secondaire de l'impédance de limitation est mis en court-circuit. Cet essai doit faire l'objet de tentatives supplémentaires dans les *conditions de premier défaut* du *composant*.

L’essai suivant s’applique aux impédances de limitation utilisées pour réduire le risque de choc électrique comme cela est décrit en S.203.1.8. L'impédance de limitation étant connectée selon S.203.2.1, une résistance de 1 500 Ω est connectée entre l'impédance de limitation et la terre. En conséquence de l'essai, le courant mesuré à travers la résistance de 1 500 Ω ne doit pas dépasser 5 mA. Cet essai doit faire l'objet de tentatives supplémentaires dans les *conditions de premier défaut* du *composant*.

Les *conditions de premier défaut* d'un *composant* de circuit d'une impédance de limitation incluent ce qui suit.

a) Pour une résistance, un condensateur, une diode ou un dispositif à semiconducteurs à deux bornes similaire, les bornes du dispositif doivent être mises en circuit ouvert ou en court-circuit.

b) Pour un dispositif discret à semiconducteurs statique comportant plus de deux bornes (un transistor, un RCS, un thyristor triode bidirectionnel ou un dispositif similaire, par exemple), toutes les combinaisons de deux bornes à la fois doivent être mises en circuit ouvert ou en court-circuit.

c) Pour un dispositif à circuit intégré, les combinaisons de bornes suivantes doivent être soumises à l'essai:
   1) chaque paire de bornes adjacentes mises en court-circuit;
   2) chaque borne d'entrée mise en court-circuit par rapport à la borne de terre;
   3) chaque borne de sortie mise en court-circuit par rapport à la borne de terre;
   4) chaque borne d'entrée mise en court-circuit par rapport à chaque alimentation;
   5) chaque borne de sortie mise en court-circuit par rapport à chaque alimentation;
   6) chaque borne mise en court-circuit.
d) Il n'est pas exigé d'évaluer une seule résistance servant d'impédance de limitation dans les *conditions de premier défaut* du *composant*.
e) Il n'est pas exigé d'évaluer un seul condensateur servant d'impédance de limitation satisfaisant aux exigences de l'UL 60384-14, dans les *conditions de premier défaut* du *composant*.

S.203.2.5 Essai du secondaire à tension limitée

La source isolée étant connectée selon S.203.2.1, une source isolée qui n'est pas fournie avec la protection du secondaire contre les *surintensités* doit être soumise à cet essai. En conséquence de l'essai, l'*isolation* du conducteur ne doit présenter aucun ramollissement ni aucune décoloration.

Chaque circuit secondaire de la source isolée fonctionne avec le secondaire mis en court-circuit jusqu'à ce que des conditions limites se produisent. L'ouverture d'un dispositif de protection intégré ou des températures constantes sont des signes de conditions limites.

S.203.2.6 Essai d'alimentation isolée

La source isolée étant connectée selon S.203.2.1, la tension en circuit ouvert du secondaire ne doit pas dépasser 150 V et la puissance de court-circuit calculée selon cet essai ne doit pas dépasser 10 000 VA.

La puissance de court-circuit maximale dont dispose le circuit secondaire à l'étude est égale au produit de la tension en court-circuit mesurée et du courant de court-circuit maximal mesuré de la source isolée, les dispositifs de protection étant contournés.

S.203.3 Circuits alimentés par une batterie

S.203.3.1 Circuits de batterie au lithium

Un circuit de batterie au lithium doit satisfaire aux exigences de l'UL 1642 et à l'un des éléments suivants:

a) les exigences du présent document relatives au circuit primaire;
b) les exigences du S.203.1.

S.203.3.2 Circuits de batterie non-lithium

Un circuit de batterie non-lithium est un circuit primaire ou secondaire dont la puissance est fournie par des batteries non-lithium rechargeables ou pas.

Un circuit de batterie non-lithium doit satisfaire aux conditions suivantes:

a) les exigences du S.203.3.3 relatives aux batteries non rechargeables primaires ou du S.203.3.4 relatives aux batteries rechargeables/non rechargeables secondaires;

b) les exigences du présent document relatives au circuit primaire ou les exigences du S.203.1.

S.203.3.3 Primaire non rechargeable

Un circuit de batterie non-lithium non rechargeable primaire doit comporter une batterie dont une sortie satisfait aux exigences d'un circuit secondaire de classe 2 ou à tension/courant limité.

S.203.3.4 Secondaire rechargeable/non rechargeable

Un circuit de batterie non-lithium rechargeable/non rechargeable secondaire doit comporter une batterie dont une sortie satisfait aux exigences d'un circuit secondaire de classe 2 ou à tension/courant limité.

Un circuit de charge pour ces circuits de batterie doit être déduit d'une source isolée satisfaisant aux exigences de circuit de classe 2, de circuit à tension/courant limité ou de circuit à énergie limitée du S.203.1.

S.204 Courants de fonctionnement du moteur à pleine charge

Le Tableau S.29 et le Tableau S.30 établissent une corrélation entre les caractéristiques assignées de cheval-vapeur du moteur et les courants de fonctionnement du moteur à pleine charge pour différentes caractéristiques assignées de tension du moteur et un certain nombre de phases.

Tableau S.29 – Courants de fonctionnement du moteur à pleine charge, en ampères, correspondant à différentes caractéristiques assignées de cheval-vapeur en courant alternatif

HP	110 V à 220 V			220 V à 240 V			360 V à 380 V [a, b]		440 V à 480 V			550 V à 600 V		
	Mono phasé	Bipha sé	Tripha sé e	Mono phasé	Bipha sé	Tripha sé e	Mono phasé	Tripha sé e	Mono phasé	Bipha sé	Tripha sé e	Mono phasé	Bipha sé	Tripha sé e
1/10	3,0			1,5			1,0							
1/8	3,8			1,9			1,2							
1/6	4,4			2,2			1,4							
1/4	5,8			2,9			1,8							
1/3	7,2			3,6			2,3							
1/2	9,8	4,0	4,4,	4.9,	2,0	2,2	3,2	1,3	2,5	1,0	1,1	2,0	0,8	0,9
3/4	13,8	4,8	6,4	6,9	2,4	3,2	4,5	1,8	3,5	1,2	1,6	2,8	1,0	1,3
1	16,0	6,4	8,4	8,0,	3.2	4,2	5,1	2,3	4,0	1,6	2,1	3,2	1,3	1,7
1-1/2	20,0	9,0	12,0	10,0	4,5	6,0	6,4	3,3	5,0	2,3	3,0	4,0	1,8	2,4
2	24,0	11,8	13,6	12,0	5,9	6,8	7,7	4,3	6,0	3,0	3,4	4,8	2,4	2,7
3	34,0	16,6	19,2	17,0	8,3	9,6	10,9	6,1	8,5	4,2	4,8	6,8	3,3	3,9
5	56,0	26,4	30,4	28,0	13,2	15,2	17,9	9,7	14,0	6,6	7,6	11,2	5,3	6,1
7-1/2	80,0	38,0	44,0	40,0	19,0	22,0	27,0	14,0	21,0	9,0	11,0	16,0	8,0	9,0
10	100	48,0	56,0	50,0	24,0	28,0	33,0	18,0	26,0	12,0	14,0	20,0	10,0	11,0
15	135	72,0	84,0	68,0	36,0	42,0	44,0	27,0	34,0	18,0	21,0	27,0	14,0	17,0
20		94,0	108	88,0	47,0	54,0	56,0	34,0	44,0	23,0	27,0	35,0	19,0	22,0
25		118	136	110	59,0	68,0	70,0	44,0	55,0	29,0	34,0	44,0	24,0	27,0
30		138	160	136	69,0	80,0	87,0	51,0	68,0	35,0	40,0	54,0	28,0	32,0
40		180	208	176	90,0	104	112	66,0	88,0	45,0	52,0	70,0	36,0	41,0
50		226	260	216	113	130	139	83,0	108	56,0	65,0	86,0	45,0	52,0
60					133	154		103		67,0	77,0		53,0	62,0
75					166	192		128		83,0	96,0		66,0	77,0
100					218	248		165		109	124		87,0	99,0
125						312		208		135	156		108	125
150						360		240		156	180		125	144
200						480		320		208	240		167	192
250						602		403			302			242
300								482			361			289
350								560			414			336
400								636			477			382
500								786			590			472

[a] Pour obtenir les courants à pleine charge pour des moteurs de 200 V et de 208 V, augmenter les caractéristiques assignées entre 220 V et 240 V correspondantes de 15 % et 10 %, respectivement.

[b] Pour obtenir les courants à pleine charge pour des moteurs de 265 V et de 277 V, diminuer les caractéristiques assignées entre 220 V et 240 V correspondantes de 13 % et 17 %, respectivement.

Tableau S.30 – Courants de fonctionnement du moteur à pleine charge, en ampères, correspondant à différentes caractéristiques assignées de cheval-vapeur en courant continu

HP	90 V	110 V à 120 V	180 V	220 V à 240 V	500 V	550 V à 600 V
1/10		2,0		1,0		
1/8		2,2		1,1		
1/6		2,4		1,2		
1/4[a]	4,0	3,1	2,0	1,6		
1/3	5,2	4,1	2,6	2,0		
1/2	6,8	5,4	3,4	2,7		
3/4	9,6	7,6	4,8	3,8		1,6
1	12,2	9,5	6,1	4,7		2,0
1-1/2		13,2	8,3	6,6		2,7
2		17,0	10,8	8,5		3,6
3		25,0	16	12,2		5,2
5		40,0	27,0	20,0		8,3
7-1/2		58,0		29,0		12,2
10		76,0		38,0		16,0
15		110,0		55,0	27,0	24,0
20		148,0		72,0	34,0	31,0
25		184,0		89,0	43,0	38,0
30		220,0		106,0	51,0	46,0
40		292,0		140,0	67,0	61,0
50		360,0		173,0	83,0	75,0
60				206,0	99,0	90,0
75				255,0	123,0	111,0
100				341,0	164,0	148,0
125				425,0	205,0	185,0
150				506,0	246,0	222,0
200				675,0	330,0	294,0

[a] Le courant à pleine charge pour un moteur 1/4 hp, 32 V en courant continu est de 8,6 A.

Annex T
(informative)

Exigences inhérentes à certains pays – Tension jusqu'à 34,5 kV au Canada

T.0 Généralités

Les articles suivants s’appliquent aux *BDM/CDM/PDS* destinés à être installés au Canada. Ces exigences viennent en complément, modifient ou suppriment les exigences des précédentes sections du présent document. Sauf indication contraire, ces exigences viennent en complément des exigences d'origine du document. La liste actuelle et exhaustive des différences nationales pour le Canada est publiée dans la CSA C22.2 No.274-17.

Les articles de l’Annex T suivent la numérotation du corps du document. La structure principale du présent document est transposée dans la présente Annex T et les titres sont insérés sous la forme de liens actifs permettant d’atteindre facilement le texte IEC applicable. Chaque élément numéroté supplémentaire est numéroté à partir de 200.

NOTE La CSA C22.2 No.274-17 est destinée à être remplacée par la CSA C22.2 No.61800-5-1.

T.1 Domaine d’application

Remplacement de l’Article 1:

1) le présent document s'applique
   a) à l'entraînement à vitesse variable (*BDM/CDM)* relié à des tensions de *réseau* jusqu'à 34,5 kV, 50 Hz en courant alternatif ou 60 Hz en courant continu;
   b) à un *PDS intégré* (ici appelé *PDS*) dont le moteur et le *BDM/CDM/PDS* sont mécaniquement intégrés dans une seule unité;
   c) Le *BDM/CDM/PDS* est destiné à être utilisé dans des emplacements ordinaires conformes au Canadian Electrical Code, Part I; et
   d) Les *BDM/CDM/PDS* sont destinés à être utilisés dans une plage de *températures ambiantes* comprise entre 0 °C et 40 °C.
2) le présent document ne s'applique pas
   a) aux commandes de vitesse de moteur monophasé à semiconducteurs assignées à 300 V/20 A au maximum et qui sont couvertes par la CSA C22.2 No. 156;
   b) aux moteurs couverts par la CSA C22.2 No. 100; et
   c) aux *BDM/CDM/PDS* reliés par un cordon.

T.2 Références normatives

Remplacement de l’Article 2:

C22.1:21, *Canadian Electrical Code (CEC) – Part I*

CSA C22.2 No. 0:20, *General requirements – Canadian Electrical Code – Part II*

CSA C22.2 No. 0.2:16 (R2020), *Insulation coordination*

C22.2 No. 0.4-17, *Bonding of Electrical Equipment*

CSA C22.2 No. 0.5:16 (R2020), *Threaded conduit entries*

CSA C22.2 No. 4:16 (R2020), *Enclosed and dead-front switches*

CSA C22.2 No. 5:16 (R2021), *Molded-case circuit breakers, molded-case switches and circuit-breaker enclosures*

C22.2 No. 14-18, *Industrial control equipment*

CAN/CSA-C22.2 No. 0.17-00 (R2018), *Evaluation of Properties of Polymeric Materials*

CAN/CSA-C22.2 No. 65-18, *Wire connectors*

C22.2 No. 66.3-06 (R2020), *Low voltage transformers – Part 3: Class 2 and Class 3 transformers*

CSA C22.2 No.77:14 (R2019), *Motors with inherent overheating protection*

CSA C22.2 No. 94.1:15 (R2020), *Enclosures for electrical equipment, non-environmental considerations*

CSA C22.2 No. 94.2:20, *Enclosures for electrical equipment, environmental considerations*

CSA C22.2 No. 100:14 (R2019), *Motors and generators*

CSA C22.2 No. 248.16:00 (R2019), *Low-voltage fuses – Part 16: Test limiters*

C22.2 No. 253:20, *Medium-voltage ac contactors, controllers, and control centres*

C22.2 No. 269.5-17, *Surge protective devices – Type 5 – Components*

CSA-C22.2 No. 4248.9:07 (R2021), *Fuseholders – Part 9: Class K*

CSA-C22.2 No. 60529:16 (R2021), *Degrees of protection provided by enclosures (IP code)*

CSA C235:19, *Preferred voltage levels for ac systems, 0 to 50 000 V*

ASTM (American Society for Testing and Materials)

D1868-07, *Standard Test Method for Detection and Measurement of Partial Discharge (Corona) Pulses in Evaluation of Insulation Systems*

D3638-12, *Standard Test Method for Comparative Tracking Index of Electrical Insulating Materials*

D3874-12, *Standard Test Method for Ignition of Materials by Hot Wire Sources*

IEEE (Institute of Electrical and Electronics Engineers)

IEEE 4-1995, *IEEE Standard Techniques for High-Voltage Testing*

IEEE C37.09-1999, *IEEE Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis*

T.3 Termes et définitions

T.3.7
isolation principale
Remplacement du 3.7 par l'isolation principale de la CSA C22.2 No. 0.

T.3.11
distance d'isolement
Remplacement du 3.11 par la distance d'isolement de la CSA C22.2 No. 0.

T.3.12
circuit de commande
Remplacement du 3.12 par le circuit de commande de la CSA C22.1 CE Code, Part I.

T.3.18
ligne de fuite
Remplacement du 3.18 par la ligne de fuite de la CSA C22.2 No. 0.

T.3.32
très basse tension
Remplacement du 3.32 par la très basse tension de la CSA C22.1 CE Code, Part I.

T.3.40
BDM/CDM/PDS haute tension
Remplacement du 3.40 par le BDM/CDM/PDS haute tension de la CSA C22.1 CE Code, Part I.

T.3.45
partie active
Remplacement du 3.45 par la partie active de la CSA C22.1 CE Code, Part I.

T.3.46
basse tension
Remplacement du 3.46 par la basse tension de la CSA C22.1 CE Code, Part I.

T.3.70
isolation renforcée
Remplacement du 3.70 par l'isolation renforcée de la CSA C22.2 No. 0.

T.3.84
isolation supplémentaire
Remplacement du 3.84 par l'isolation supplémentaire de la CSA C22.2 No. 0.

Termes et définitions supplémentaires:

T.3.200
microenvironnement
conditions qui entourent immédiatement une *distance d'isolement* ou une *ligne de fuite*

Note 1 à l'article: Les conditions microenvironnementales, plutôt que l'environnement général, déterminent les effets sur l'*isolation*. Un microenvironnement peut être plus ou moins sévère que l'environnement général et inclut tous les facteurs ayant un impact sur l'*isolation* (le climat, l'électromagnétisme et la pollution, par exemple).

T.3.201
régulation de limitation de courant temporisée
régulation de limitation de courant qui intègre un dispositif de temporisation pour couper ou réduire le courant de sortie

T.3.202
courant de déclenchement
courant de sortie du *BDM/CDM/PDS* auquel la fonction de surcharge du moteur est déclenchée

T.4 Protection contre les dangers

T.4.1 Généralités

Ajout à 4.1:

1) les exigences générales applicables au présent document sont données dans la dernière édition de la CSA C22.2 No.0;
2) aucune exigence n'est formulée pour les *composants* de circuits secondaires qui sont
   a) alimentés par
      i) un transformateur qui satisfait aux exigences d'un transformateur pour un circuit de Classe 2, comme cela est spécifié dans la CSA C22.2 No. 66.3;
      ii) une alimentation isolée dont le dispositif de protection contre les *surintensités* est assigné à 5 A max pour les tensions en circuit ouvert de 20 V en valeur efficace maximale et 100/V pour les tensions supérieures à 20 V jusqu'à 30 V en valeur efficace; ou
      iii) une combinaison transformateur/impédance qui limite le courant à 5 A, dans les conditions de charge non capacitive, mesuré 1 min après la mise sous tension, pour des tensions en circuit ouvert de 20 V en valeur efficace au maximum et 100/V pour des tensions supérieures à 20 V jusqu'à 30 V en valeur efficace; et
   b) ne sont pas des circuits de sécurité.
3) un contacteur dans un circuit de puissance utilisé dans un *BDM/CDM/PDS* doit être adapté au contrôle de la charge connectée, y compris l'établissement, le transport et la coupure du courant de charge. Un contacteur présentant des caractéristiques assignées inférieures peut être utilisé s'il est verrouillé ou séquencé de sorte que, dans des conditions normales de fonctionnement, il fonctionne dans ses caractéristiques assignées propres.

T.4.2 *Conditions de* premier *défaut et conditions anormales de fonctionnement*

T.4.3 Protection contre les courts-circuits et les surcharges

T.4.3.1 Généralités

Ajout à 4.3.1:

Le paragraphe T.4.13.6.200, 4), 5) et 7), s'applique.

Modification du 4.3.1:

L'IEC 60364-4-41:2005 et l'IEC 60364-4-41:2005/AMD1:2017, 411.3.2 et 415.2, ne s'appliquent pas.

T.4.3.2 Valeurs assignées de court-circuit en *entrée et courant* disponible *de court-circuit en sortie*

T.4.3.3 Coordination de court-circuit (protection en amont)

T.4.3.4 Protection par plusieurs dispositifs

T.4.3.5 Protection contre la surchauffe et contre les surcharges du moteur

T.4.3.5.1 Moyens de protection

Remplacement du 4.3.5.1 par le paragraphe T.4.13.6.200, 8) 21)g).

T.4.4 Protection contre les chocs électriques

T.4.4.1 Généralités

T.4.4.2 *Classe de tension déterminante (CTD)*

T.4.4.3 Dispositions en matière de *protection principale*

T.4.4.3.3 Protection au moyen d’enveloppes ou de barrières

Remplacement du 4.4.3.3:

Les *parties actives* doivent être placées dans des *enveloppes* ou derrière des barrières, qui doivent satisfaire au T.4.12.

T.4.4.4 Dispositions en matière de *protection en cas de défaut*

T.4.4.4.1 Généralités

T.4.4.4.2 *Liaison équipotentielle de protection*

T.4.4.4.2.1 Généralités

Ajout à 4.4.4.2.1:

Le *BDM/CDM/PDS* doit satisfaire aux exigences de la CSA C22.2 No. 0.4, sauf que le courant d'essai pour l'essai d'impédance doit dépendre de la valeur assignée en ampère du dispositif.

Modification du 4.4.4.2.1:

Le paragraphe 4.4.4.2.1 b) ne s’applique pas.

T.4.4.4.2.2 Caractéristiques de *la liaison équipotentielle* de protection

Le paragraphe 4.4.4.2.2 b) ne s’applique pas.

T.4.4.4.3 *Conducteur de mise à la terre de protection*

T.4.4.4.3.1 Généralités

Modification du 4.4.4.3.1:

La dimension du *conducteur de mise à la terre de protection* doit être conforme au T.4.4.4.3.2 4) et sa couleur doit être conforme à la CSA C22.2 No. 0.4.

Remplacement du Tableau 4 *par le Tableau T.2.*

T.4.4.4.3.2 Dispositifs de raccordement du conducteur *de mise à la terre de protection*

Modification du 4.4.4.3.2:

1) des dispositions en matière de mise à la terre et de liaison équipotentielle du *BDM/CDM/PDS* doivent être prévues et se terminer de l'une des manières suivantes en T.4.4.4.3.2 2) ou par des kits de mise à la terre et de liaison équipotentielle approuvés;
2) les terminaisons de liaison équipotentielle doivent être prévues pour au moins le nombre suivant de conducteurs de liaison:
   a) *enveloppes* de dispositif de puissance: un conducteur de liaison pour chaque circuit de puissance entrant et sortant, reposant sur un circuit pour trois pôles au maximum et un circuit tous les trois pôles supplémentaires au maximum, plus un conducteur de liaison pour le *circuit de commande*, selon le cas;
   b) enveloppes en métal coulé pour les dispositifs de puissance pour lesquels des dispositions sont prévues pour une seule entrée de conduit: un conducteur de liaison;
   c) *enveloppes* de dispositif auxiliaires: un conducteur de liaison;
3) le nombre maximal de conducteurs sur chaque terminaison doit être déterminé selon le Tableau T.1.

Tableau T.1 – Dimension et nombre de conducteurs de liaison par terminaison

Type de terminaison	Dimension de conducteur maximal AWG	Nombre maximal de conducteurs
Tête de vis de serrage	No. 10	1
Vis avec moyen de retenue	No. 10	2
Serre-fils selon la CAN/CSA-C22.2 No. 65 (a) un seul conducteur (b) plusieurs conducteurs (c) type à serrage	Tel que certifié Tel que certifié Tel que certifié	1 [a] Tel que certifié [a] 2

[a] Si un connecteur est certifié pour une plage de dimensions de conducteur, plusieurs conducteurs peuvent être insérés dans un connecteur, à condition que les conducteurs soient torsadés ensemble avant de les insérer dans le connecteur, auquel cas un marquage doit apparaître sur le *BDM/CDM/PDS* (voir T.6.2.1.200 3)). Les conducteurs supérieurs à No. 6 AWG ne doivent pas être torsadés ensemble.

4) pour déterminer l'aptitude de la terminaison de liaison équipotentielle, la dimension du conducteur de liaison doit être
   a) No. 14 AWG cuivre ou No. 12 AWG aluminium pour les *circuits de commande* et les dispositifs auxiliaires; ou
   b) choisie dans le Tableau T.2 pour les circuits et dispositifs de puissance.

NOTE Les interrupteurs de fin de course, les interrupteurs à bouton-poussoir et les relais sont des exemples de dispositifs auxiliaires.

Tableau T.2 – Dimension du conducteur de liaison

Caractéristique assignée du circuit A	Dimension minimale du conducteur de liaison AWG		Dimension du conduit ou tuyau métallique AWG	Dimension du tuyau métallique électrique AWG
	Fil en cuivre	Fil en aluminium		
20 30 40 60	14 12 10 10	12 10 8 8	1/2 1/2 1/2 3/4	1/2 1/2 1 1
100 200 300 400	8 6 4 3	6 4 2 1	1 1-1/4 1-1/4 2-1/2	1-1/4 1-1/2 1-1/2 2-1/2
500 600 800	2 1 0	0 00 000	2-1/2 3 4	2-1/2 4 4
1 000 1 200 1 600 2 000	00 000 0000 250 kcmil	0000 250 kcmil 350 kcmil 400 kcmil	4 6 — —	4 — — —
2 500 3 000 4 000 5 000 6 000	350 kcmil 400 kcmil 500 kcmil 700 kcmil 800 kcmil	500 kcmil 600 kcmil 800 kcmil 1 000 kcmil 1 250 kcmil	— — — — —	— — — — —

5) Pour les *enveloppes* polymères

a) Une *enveloppe* utilisant un matériau isolant, en tout ou en partie, doit comporter des moyens adaptés de liaison équipotentielle pour assurer la continuité de la liaison équipotentielle entre toutes les ouvertures de conduit et toutes les parties métalliques externes qui peuvent être mises sous tension. Ces moyens de liaison équipotentielle doivent être complètement assemblés sur le produit ou être fournis en pièces détachées pour une installation sur site. Une *enveloppe* conçue pour un assemblage sur site des moyens de liaison équipotentielle doit être accompagnée d'instructions exhaustives afin d'assurer une installation correcte. Les instructions doivent inclure une identification des parties concernées et leur méthode d'installation (voir T.6.2.1.200 4)).

b) Un conducteur de liaison séparé doit être en cuivre, en alliage de cuivre ou en matériau adapté à une utilisation en tant que conducteur électrique. Les parties en métal ferreux dans le trajet de mise à la terre doivent être correctement protégées contre la corrosion par émaillage, galvanisation, plaquage ou d'autres moyens équivalents. Un conducteur de liaison séparé

i) doit être protégé contre les dommages mécaniques ou être placé à l'intérieur de l'*enveloppe* extérieure ou du châssis, et

ii) ne doit pas être fixé par une fixation amovible utilisée pour tout autre chose que la liaison équipotentielle. Les extrémités du conducteur de liaison doivent être en contact métal sur métal avec les parties à lier.

c) La dimension d'un conducteur de liaison de *composant* séparé ne doit pas être inférieure à la dimension spécifiée dans le Tableau T.2 ou à la taille du conducteur qui alimente le *composant*, si celle-ci est plus petite.

d) Des moyens doivent être prévus pour faciliter la liaison à la terre des secondaires des transformateurs de *circuit de commande*.

e) Les circuits secondaires du transformateur de mesure doivent être reliés à la terre. Ce type de mise à la terre doit être réalisé, sans fusible dans le circuit de mise à la terre, directement au câble de mise à la terre (ou au goujon en l'absence de câble de mise à la terre) et les conducteurs de mise à la terre ne doivent pas être utilisés pour relier à la terre les parties métalliques non porteuses de courant.

   Il existe des *systèmes* de relais si la mise à la terre au niveau de l'équipement n'est pas faisable. Dans de tels cas, il est nécessaire de ne relier à la terre qu'un seul point adapté dans le réseau secondaire du transformateur.

T.4.4.4.3.3 *Courant de contact* en cas de défaillance du *conducteur de mise à la terre de protection*

Le paragraphe 4.4.4.4.3 ne s'applique pas.

T.4.4.5 Mesures de *protection renforcée*

T.4.4.6 Mesures de protection

T.4.4.7 *Isolation*

T.4.4.7.1 Facteurs d'influence

T.4.4.7.1.1 Généralités

Modification du 4.4.7.1.1:

Le *système* d'*isolation* du moteur doit satisfaire à la CSA C22.2 No. 100 ou à la C22.2 No.77.

Ajout à 4.4.7.1.1:

les *distances d'isolement* et *lignes de fuite* au niveau des fusibles et des porte-fusibles, mesurées avec les fusibles en place, doivent s'appuyer sur des fusibles aux dimensions normalisées maximales.

Tableau T.3 – *Distances d'isolement* et *lignes de fuite* minimales sur les *bornes pour câblage externe*

Groupe		Tension nominale concernée V	*Distances d'isolement* minimales, air mm			
			Entre les *parties actives* nues de polarité opposée et entre les *parties actives* nues et les parties métalliques reliées à la terre autres que l'*enveloppe*		Entre les *parties actives* nues et les parois d'*enveloppes* métalliques, y compris les fixations du conduit ou le câble blindé *	
			Distance d'isolement	*Ligne de fuite*	*Distance d'isolement*	*Ligne de fuite*
A	Appareil de commande industriel général	51 à 150 151 à 300 301 à 600 601 à 1 000 1 001 à 1 500	3,0 6,3 9,4 14,0 17,8	6,3 9,4 12,7 21,6 30,5	12,7 12,7 12,7 20,3 30,5	12,7 12,7 12,7 25,4 41,9
		601 à 1 000 1001 à 1 500 2 500 7 200 15 000 34 500	11,4 15,2 25,4 50,8 101,6 150	15,7 17,8 50,8 88,9 124,3 200	20,3 30,5 50,8 76,2 101,6 125	25,4 41,9 76,2 102 127 145
B	Dispositifs ayant des caractéristiques assignées limitées	51 à 150 151 à 300 301 à 600	1,5 [a] 1,5 [a] 4,6 [a]	1,5 [a] 3,0 [a] 9,4	6,3 6,3 12,7	6,3 6,3 12,7
C	Autres petits dispositifs	51 à 150 151 à 300	3,0 [a] 6,3	6,3 6,3	6,3 6,3	6,3 6,3

[a] La *distance d'isolement* et *lignes de fuite* entre les bornes de câblage de polarité opposée et la *distance d'isolement* et *lignes de fuite* entre une borne pour câblage et une partie métallique non porteuse de courant reliée à la terre ne doivent pas être inférieures à 6,3 mm si la mise en court-circuit ou la mise à la terre de ces bornes peut entraîner des projections de brins de fil.

Paragraphe supplémentaire:

T.4.4.7.1.200 *Distance d'isolement* et *lignes de fuite*

1) La distance d'isolement et les *lignes de fuite* au niveau d'une *borne pour câblage externe* doivent être mesurées avec une dimension de calibre appropriée correspondant à la caractéristique assignée connectée à la borne comme en service réel, et doivent être conformes au Tableau T.3.

   Dans un circuit comprenant des tensions de 50 V au maximum, la *distance d'isolement* et les *lignes de fuite* dans les *bornes pour câblage externe* peuvent être de 3,2 mm dans l'air et de 6,3 mm sur la surface.

2) Dans un *BDM/CDM* de *type ouvert*, les *distances d'isolement* et *lignes de fuite* entre les *parties actives* et les parties métalliques qui peuvent être reliées à la terre (les têtes de vis de montage qui traversent un panneau isolant, par exemple) doivent être évaluées comme si les parties étaient reliées à la terre à l'intérieur d'une *enveloppe*. La distance d'isolement et les *lignes de fuite* entre des *parties actives* nues et la surface sur laquelle le dispositif peut être monté doit être évaluée comme si la surface de montage faisait partie intégrante d'une *enveloppe*.

3) La *distance d'isolement* et les *lignes de fuite* ne sont pas spécifiées pour un circuit dont la tension ne dépasse pas 30 V et qui est alimenté par une batterie principale, un transformateur de classe 2 normalisé ou une combinaison pertinente d'un transformateur et d'une impédance fixe dont les caractéristiques de sortie satisfont aux exigences d'un transformateur de classe 2. Dans la zone du câblage externe, les dispositions en matière de câblage de ces circuits doivent être séparées des autres circuits conformément à la CSA C22.1 CEC, règle 16-212, 16-214.

4) Si des bras de contact, des pales, etc. dans un *PDS* restent reliés aux bornes de charge du moteur en position désactivée (OFF), la *distance d'isolement* et les *lignes de fuite* entre ces parties en position désactivée (OFF) et l'*enveloppe* ou les parties métalliques non porteuses de courant exposées isolées, venant en complément mais ne remplaçant pas les *distances d'isolement* et *lignes de fuite* exigées par ailleurs, ne doit pas être inférieure à 3,2 mm. Dans un circuit en série, les *distances d'isolement* et *lignes de fuite* entre les bornes de la résistance, les prises de transformateur, etc. doivent dépendre de la tension de fonctionnement normale qui existe entre ces parties.

5) Les joints d'étanchéité, s'ils sont utilisés pour obtenir les *distances d'isolement* et *lignes de fuite* exigées, doivent être adaptés à l'application. Ils doivent être montés de manière à ne pas être aisément endommagés et doivent être maintenus fermement en position.

6) Si une *distance d'isolement* ou des *lignes de fuite* entre une *partie active* nue et une traversée installée dans l'ouverture défonçable sont mesurées, il doit être pris pour hypothèse qu'une traversée avec les dimensions spécifiées dans le Tableau T.4 est en place, avec un seul écrou de blocage installé sur l'extérieur de l'*enveloppe*.

7) Une *partie active* nue, y compris une borne, doit être fixée à sa surface de support par une méthode autre que le frottement entre les surfaces, et est empêchée de tourner ou de se déplacer dans une position qui, si ce type de mouvement se produit, peut réduire la *distance d'isolement* et les *lignes de fuite* à des valeurs inférieures à celles exigées par les paragraphes 4.4.1 à 4.4.7. La sécurité d'un ensemble de contact doit assurer l'alignement permanent des contacts.

8) Il n'est pas nécessaire d'empêcher le pivotement d'un connecteur de borne à pression, à condition que le fait de tourner les bornes de 30 ° l'une vers l'autre, vers d'autres parties non isolées de polarité opposée ou vers des parties métalliques reliées à la terre ne réduise pas la *distance d'isolement* et les *lignes de fuite* à une valeur inférieure à celles exigées.

9) Une tête de vis ou un écrou actif au dos d'un socle isolant ne doit pas se desserrer et doit être correctement isolé ou espacé par rapport à la surface de montage. Cela doit être réalisé en fraisant ces parties à 3,2 mm au maximum, puis en les recouvrant d'un matériau isolant étanche à l'eau qui ne fond pas à une température 15 °C supérieure à sa température de fonctionnement normal dans le dispositif (pas moins de 65 °C dans tous les cas). Ces parties peuvent être également fixées et isolées de la surface de montage au moyen d'une barrière, ou un équivalent, ou par des *distances d'isolement* et des *lignes de fuite* dans l'air ou sur la surface spécifiées dans le Tableau T.3.

Tableau T.4 – Dimensions des traversées

Dimension commerciale du conduit in	Dimensions de la traversée mm	
	Diamètre global	**Hauteur**
1/2	25,4	9,5
3/4	31,4	10,7
1	40,5	13,1
1-1/4	49,2	14,3
1-1/2	56,0	15,1
2	68,7	15,8
2-1/2	81,8	19,1
3	98,4	20,6
3-1/2	112,7	23,8
4	126,2	25,4
4-1/2	140,9	27,0
5	158,0	30,2
6	183,4	31,8

T.4.4.7.1.2 *Tension de fonctionnement*

T.4.4.7.1.3 Degré de pollution

Modification du 4.4.7.1.3:

1) Lorsque les *BDM/CDM/PDS* sont conçus pour les autres degrés de pollution que le degré 3, le degré de pollution doit être marqué sur le *BDM/CDM/PDS* (voir T.6.3.3).
2) La catégorie de degré de pollution peut être obtenue comme suit.
   a) Le degré 1 peut être obtenu par encapsulation ou scellement hermétique du microenvironnement. Pour les cartes de circuit imprimé, des revêtements satisfaisant aux critères du 5.2.3.2 peuvent être utilisés.
   b) Le degré 2 peut être obtenu en limitant la possibilité de condensation ou d'humidité élevée au niveau d'une *ligne de fuite*, en assurant la ventilation ou l'application permanente de chaleur, par l'utilisation de chauffages ou par la mise sous tension continue de l'équipement lorsqu'il est en cours d'utilisation. La mise sous tension continue est considérée comme existante si l'équipement fonctionne sans interruption tous les jours, 24 h/24 h ou lorsque l'équipement fonctionne avec des interruptions dont la durée ne lui permet pas de refroidir au point de laisser apparaître de la condensation.
   c) Le degré 3 peut être obtenu par l'utilisation d'*enveloppes* permettant d'exclure ou de réduire les influences environnementales (l'humidité sous la forme de gouttelettes d'eau, par exemple).
   d) Le Tableau 20 ne s’applique pas.

T.4.4.7.1.4 Catégorie de surtension (OVC)

Ajout à 4.4.7.1.4:

Lorsque les *BDM/CDM/PDS* sont conçus pour les autres catégories de surtension que la catégorie de surtension III, la catégorie de surtension doit être marquée sur le *BDM/CDM/PDS* (voir T.6.3.3).

T.4.4.7.1.7.2 Pour l'alimentation *non raccordée directement au réseau*

Modification du 4.4.7.1.7.2:

L'IEC 62477-1:2022 ne s'applique pas.

T.4.4.7.2 ***Isolation* par rapport à l'environnement**

T.4.4.7.3 ***Isolation fonctionnelle***

T.4.4.7.4 ***Distance d'isolement***

T.4.4.7.5 ***Lignes de fuite***

T.4.4.7.6 **Revêtement ou empotage**

T.4.4.7.7 ***Distance* d'isolement *et lignes* de *fuite d'une* carte de circuit *imprimé* et des composants assemblés sur une carte de circuit imprimé pour une *isolation fonctionnelle***

Ajout à 4.4.7.7:

Il est admis de diminuer la *distance d'isolement* et les *lignes de fuite* sur la carte de circuit imprimé lorsque la *distance d'isolement* et les *lignes de fuite* ne sont pas utilisées dans un circuit de sécurité.

T.4.4.7.8 ***Isolation solide***

T.4.4.7.8.1 **Généralités**

T.4.4.7.8.2 **Exigences du matériau**

Ajout à 4.4.7.8.2:

Un matériau isolant dont l'épaisseur est inférieure à celle spécifiée en 4.4.7.8.2 et en 4.4.7.8.3 peut être utilisé dans un *BDM/CDM/PDS* assigné à 600 V et moins si le matériau isolant est

a) soumis à un essai de tenue en tension diélectrique pendant 60 s en utilisant la *tension de tenue aux chocs* indiquée dans le Tableau T.5 ou la tension d'essai en courant alternatif en valeur efficace indiquée dans le Tableau T.6 selon le cas, correspondant à la *distance d'isolement* exigée, ou

b) choisi dans le Tableau T.7. Ce matériau générique doit être considéré comme étant adapté pour l'application sans l'essai de tenue en tension diélectrique.

Tableau 13 – Matériaux génériques pour le matériau *isolant*

Ajout à Tableau 13*:*

Dans les autres cas, le matériau isolant doit être conforme à l'essai au fil incandescent décrit dans la CSA C22.2 No. 0.17 à une température d'essai de 850 °C. L'autre essai d'inflammation au fil chaud de la CSA C22.2 No. 0.17 peut être utilisé.

L'IEC 60695-2-11:2021 et l'IEC 60695-10-2:2014 ne s'appliquent pas.

T.4.4.7.8.3 Matériau pelliculé ou ruban

T.4.4.7.8.4 Cartes de circuit imprimé

T.4.4.7.8.4.3 Utilisation d’un matériau de revêtement

Le paragraphe 4.4.7.8.4.3 ne s’applique pas.

T.4.4.7.8.5 Matériaux d'empotage

Ajout à 4.4.7.8.5:

Les bases et supports thermoplastiques moulés doivent être soumis à l'essai de déformation par réduction des contraintes de moulage du 5.2.2.4.5, selon le cas.

Tableau T.5 – Tensions d'essai pour vérifier les *distances d'isolement*

Distance dans l'air minimale spécifiée dans la norme de produit fini mm	**Tensions d’essai** kV				
	tension de tenue aux chocs courant alternatif crête ou courant continu				
	Altitude[a] m (pression atmosphérique, kPa)[b]				
	0 (101,3)	**200 (98,8)**	**500 (95,0)**	**1 000 (90,0)**	**2 000 (80,0)**
0,4	1,7	1,7	1,7	1,6	1,5
0,8	2,2	2,1	2,1	2	1,9
1,2	2,75	2,7	2,55	2,5	2,3
1,6	3,3	3,3	3,2	3	2,7
2,4	4,4	4,3	4,1	3,9	3,5
3,2	5,3	5,2	5	4,8	4,3
4,8	6,9	6,8	6,6	6,2	5,6
6,4	8,3	8,2	7,9	7,5	6,8
9,5	10,9	10,7	10,3	9,8	8,8
12,7	14	13,7	13,2	12,5	11,2
25,4	25,5	24,6	24	22,7	20,2

[a] L'altitude spécifiée inférieure suivante doit être utilisée pour les altitudes intermédiaires.

[b] Les valeurs de pression atmosphérique en kilopascals sont fournies pour permettre de procéder aux essais à des pressions simulant des élévations différentes de celles de l'installation d'essai.

Tableau T.6 – Tensions d'essai pour la vérification des *distances d'isolement* à l'aide de valeurs efficaces en courant alternatif

Distance dans l'air minimale spécifiée dans la norme de produit fini mm	Tensions d'essai kV				
	Valeur efficace en courant alternatif				
	Altitude[a] m (pression atmosphérique, kPa)[b]				
	0 (101,3)	200 (98,8)	500 (95,)	1 000 (90,0)	2 000 (80,0)
0,4	1,2	1,2	1,2	1,2	1,1
0,8	1,5	1,5	1,5	1,4	1,3
1,2	1,95	1,9	1,9	1,75	1,6
1,6	2,4	2,3	2,3	2,1	1,9
2,4	3,1	3	2,9	2,8	2,5
3,2	3,7	3,7	3,6	3,4	3
4,8	4,9	4,8	4,7	4,4	4
6,4	5,9	5,9	5,6	5,3	4,8
9,5	7,7	7,7	7,3	7	6,3
12,7	9,9	9,7	9,3	8,9	7,9
25,4	18,2	17,6	17,1	16,2	14,4

[a] L'altitude spécifiée inférieure suivante doit être utilisée pour les altitudes intermédiaires.

[b] Les valeurs de pression atmosphérique en kilopascals sont fournies pour permettre de procéder aux essais à des pressions simulant des élévations différentes de celles de l'installation d'essai.

Tableau T.7 – Matériau générique acceptable en tant que barrière

Matériau	Épaisseur minimale de la barrière mm	Épaisseur minimale de la barrière, en mm, en complément d'une utilisation complémentaire non inférieure à la moitié de la distance dans l'air exigée mm	Classe d'*isolation* °C
Papier de classe électrique	0,66	0,33	105
Papier chiffon imprégné	0,51	0,253	105
Tissu d'acétate	1,32	0,66	105
Film d'acétate	0,44	0,22	105
Cristal	0,44	0,22	105
Toile vernie	0,4	0,198	105
Polyamide	0,33	0,165	130
Film en polyéthylène téréphtalate	0,33	0,165	130
Film en polyester	0,33	0,165	130
Polybutylène téréphtalate	0,33	0,165	130
Tissu de verre imprégné de silicone	0,66	0,33	180
Papier d'aramide	0,33	0,163	220
Feuille PTFE	0,22	0,11	250
Polyimide	0,11	0,055	250

T.4.4.8 Compatibilité avec les dispositifs de protection à courant différentiel résiduel (DDR)

T.4.4.9 Décharge de condensateurs

Remplacement du 4.4.9:

Les condensateurs à l'intérieur d'un *BDM/CDM/PDS* doivent être déchargés à une tension inférieure à 50 V ou à une charge résiduelle inférieure à 50 µC, dans les limites de 1 min après la suppression de puissance du *BDM/CDM/PDS* pour des *BDM/CDM/PDS* assignés à 750 V au maximum ou dans les limites de 5 min pour les *BDM/CDM/PDS* assignés à plus de 750 V.

Si cette exigence ne peut être satisfaite pour des raisons fonctionnelles ou d'autres raisons, les informations et les exigences de marquage du 6.5.2 doivent s'appliquer. Voir 5.2.3.8 pour l'essai.

Cette exigence s'applique également aux condensateurs utilisés pour la correction du facteur de puissance, le filtrage, etc.

T.4.4.10 Conditions d'accès pour les parties *haute tension* du *BDM/CDM/PDS* (*verrouillage*)

Ajout d'un paragraphe supplémentaire à 4.4.10:

T.4.4.10.200 Conditions d'accès pour les parties haute *tension du BDM/*CDM*/*PDS (*verrouillage*)

1) Un *BDM/CDM/PDS haute tension* doit être équipé de *verrouillages* de porte mécaniques. Les *verrouillages* peuvent être activés par des moyens mécaniques ou électriques.
2) Les *verrouillages de porte* doivent être soumis à l'essai selon 5.2.2.8 et satisfaire aux exigences suivantes.
   a) Les *verrouillages* doivent empêcher l'ouverture d'une *porte* donnant accès à un compartiment haute tension lorsque les dispositifs d'*isolation* sont fermés.
   b) Les *verrouillages* doivent empêcher la fermeture des dispositifs d'isolation lorsque la *porte* d'un compartiment haute tension du contrôleur est ouverte.
   c) Si un *BDM/CDM/PDS haute tension* est réalimenté par d'autres sources de puissance (un contacteur de contournement ou un contacteur d'isolation, par exemple), des *verrouillages* doivent être prévus pour empêcher l'ouverture d'une *porte* donnant accès à un compartiment haute tension lorsque les dispositifs d'isolation de la source de puissance réalimentée est fermée, et empêcher la fermeture des dispositifs d'isolation de la source de puissance réalimentée lorsqu'une *porte* donnant accès à un compartiment haute tension est ouverte.

   NOTE 1 Les schémas de *verrouillage* par clé sont considérés comme satisfaisant à cette exigence.
3) Outre ce qui est spécifié en T.4.4.10.200 4), le *BDM/CDM/PDS haute tension* doit satisfaire aux exigences relatives à l'*enveloppe*, aux dispositifs d'isolation et de *verrouillage* et à la barrière de la CSA C22.2 No. 253.

4) Un *BDM/CDM/PDS haute tension* sans les dispositifs d'isolation indiqués doit satisfaire aux conditions suivantes.
   a) Le *BDM/CDM/PDS haute tension* doit être marqué de manière à indiquer que des dispositifs d'isolation externes sont exigés.
   b) Le *BDM/CDM/PDS haute tension* doit être accompagné d'instructions indiquant les dispositifs d'isolation externes spécifiques qui doivent être prévus.
   c) Le *BDM/CDM/PDS haute tension* doit être équipé de moyens de *verrouillage* avec les dispositifs d'isolation externes spécifiés.

   NOTE 2 Cela exige d'installer une partie du *système de verrouillage* sur le *BDM/CDM/PDS* et de livrer la partie restante (installée sur les dispositifs d'isolation externes) en kit avec le *BDM/CDM/PDS*. Ce kit doit contenir toutes les parties nécessaires du *verrouillage*, tout le matériel exigé pour installer le *verrouillage* et des instructions spécifiques détaillant l'installation du *verrouillage* sur les dispositifs d'isolation.

   d) Si le *verrouillage* est correctement installé sur les dispositifs d'isolation externes, l'assemblage obtenu doit satisfaire aux exigences de *verrouillage* et d'isolation de la CSA C22.2 No. 253.
5) Si le *BDM/CDM/PDS haute tension* est équipé d'un élément de déchargement servant de dispositif d'isolation, il doit satisfaire aux exigences applicables de la CSA C22.2 No. 253.
6) Une disposition d'au moins deux contacteurs doit faire l'objet d'un *verrouillage* mécanique et électrique afin d'empêcher un défaut entre phases s'ils sont en position fermée en même temps. Il peut s'agir, par exemple
   a) de contacteurs de contournement, et
   b) de contacteurs de freinage dynamique et de contacteurs de phase.
7) Si un moyen de contourner le *verrouillage de porte* décrit en T.4.4.10.200 2) est fourni pour procéder à l'*inspection visuelle* du 5.2.1 ou pour les besoins de la maintenance, un certain degré de difficulté de contournement du *verrouillage* doit être assuré. Le degré de difficulté doit impliquer de procéder au moins à deux opérations séparées et distinctes. Le fait de tourner un bouton, de déplacer une manette, de retirer un seul boulon, etc., ne doit pas être considéré comme assurant le degré de difficulté exigé. Si un *verrouillage* est prévu entre la *porte* et le mécanisme de commande d'un *BDM/CDM/PDS haute tension*, des dispositions peuvent être prévues pour contourner le *verrouillage* afin de procéder à l'*inspection visuelle* du 5.2.1 pendant que le commutateur est en position activée (ON). Un seul mécanisme d'annulation de l'opération peut être utilisé.
8) L'IEC 62271-102:2018 et l'IEC 61230:2008 ne s'appliquent pas.

T.4.5 Protection contre les dangers dus à l'énergie électrique

T.4.5.3 Sources de puissance limitée

Ajout à 4.5.3*:*

L'utilisation d'un dispositif à coefficient de température positif conforme à l'IEC 60730-1:2013, à l'IEC 60730-1:2013/AMD1:2015 et à l'IEC 60730-1:2013/AMD2:2020 du 4.5.3 b) ne s'applique pas.

T.4.6 Protection contre les dangers d'incendie et thermiques

T.4.6.1 Généralités

T.4.6.2 Circuits et *composants* représentant un danger d'incendie

T.4.6.3 Sélection des *composants* pour atténuer le risque d'un danger d'incendie

Modification du 4.6.3:

L'IEC 60695-11-10:2013 ne s'applique pas, remplacée par la CSA C22.2 No.0.17.

T.4.6.4 Protection contre le feu *fournie* par les *enveloppes*

T.4.6.4.1 Généralités

T.4.6.4.2 Exigences *générales* relatives à l'enveloppe

Modification du 4.6.4.2:

1) L'*enveloppe* polymère doit satisfaire à 5.2.2.4.3, 5.2.5.5 et T.5.2.2.4.200.

   Le matériau d'une *enveloppe* utilisée comme *isolation électrique* doit satisfaire à l'essai de rigidité diélectrique spécifié en T.5.2.3.4.2 entre les parties porteuses de courant et les parties métalliques non porteuses de courant exposées et/ou une feuille conductrice à l'extérieur de l'*enveloppe.*

2) Un bouchon non métallique ou une autre *fermeture* assemblée sur un boîtier en tôle comme partie intégrante de l'*enveloppe* (voir CAN/CSA-C22.2 No. 0.17), doit être considéré(e) comme étant acceptable dans l'une des conditions suivantes:

   a) la fermeture présente une surface maximale de 645 mm^2 et son matériau est classé V-0, V-1 ou V-2;

   b) la fermeture présente une surface maximale de 645 mm^2, son matériau est classé HB et elle satisfait aux exigences de l'essai de flamme du 5.2.5.5 et du T.5.2.5.5;

   c) la fermeture présente une surface maximale de 645 mm^2, son matériau est classé V-0, V-1, V-2, ou HB, et elle est utilisée comme lentille lumineuse pilote; ou

   d) la fermeture présente une surface de plus de 645 mm^2, son matériau est classé V-0, V-1, V-2, ou HB et elle satisfait aux exigences de l'essai d'inflammabilité et de l'essai de choc du 5.2.5.5, du T.5.2.5.5 et du T.5.2.2.4.200.

T.4.6.4.3 *BDM/CDM de type* ouvert destiné à être installé dans *une* enveloppe *supplémentaire ou* dans une *zone d'accès limité*

T.4.6.4.4 *BDM/CDM* conçu pour atténuer le danger d'incendie au moyen de l'enveloppe

Remplacement du 4.6.4.4:

Le *BDM/CDM* est construit dans une *enveloppe ignifuge* satisfaisant aux exigences générales en matière d'*enveloppe* du T.4.6.4.2 et du T.4.12.

T.4.6.5 Limites de température

T.4.7 Protection contre les dangers mécaniques

T.4.7.1 Généralités

T.4.7.2 Vitesse de torsion critique

T.4.7.3 Analyse du couple transitoire

T.4.7.4 Exigences spécifiques pour le BDM/*CDM/PDS refroidi* par liquide

T.4.7.4.1 Généralités

T.4.7.4.2 Liquide de refroidissement

T.4.7.4.3 Exigences de la conception

T.4.7.4.3.1 Généralités

T.4.7.4.3.2 Résistance à la corrosion

T.4.7.4.3.3 Tuyauterie, durites et joints d’étanchéité

T.4.7.4.3.4 Disposition pour la condensation

T.4.7.4.3.5 Conductivité du liquide de refroidissement

T.4.7.4.3.6 Fuite du liquide de refroidissement

Ajout à 4.7.4.3.6:

Le liquide de refroidissement libéré après le fonctionnement d'un limiteur de pression ne doit pas s'écouler dans le compartiment électrique.

T.4.8 *BDM/CDM/PDS* à plusieurs sources d’alimentation

T.4.9 Protection contre les contraintes environnementales

T.4.9.1 Généralités

Modification du 4.9.1:

1) Il n'est pas exigé de déclarer la résistance à l'humidité, aux vibrations et aux ultraviolets.
2) Le degré de pollution est exigé lorsqu’il est différent du degré de pollution 3, voir T.4.4.7.1.3 1).
3) La température ambiante est exigée lorsqu’elle est différente de 40 °C.
4) Le Tableau 20 ne s’applique pas.

T.4.10 Protection contre les dangers de bruit acoustique excessif

Le paragraphe 4.10 ne s’applique pas.

T.4.11 Câblage et raccordements

T.4.11.1 Généralités

Ajout à 4.11.1:

1) Les conducteurs ne doivent pas être plus petits que No. 24 AWG, et la température nominale ne doit pas être inférieure à 90 °C, sauf si un examen prouve la pertinence des autres conducteurs.

   Les exigences du T.4.11.1 s'appliquent uniquement au câblage faisant partie intégrante du *BDM/CDM/PDS*. Elles ne s'appliquent pas au câblage d'alimentation du *BDM/CDM/PDS*, aux moteurs ou à d'autres appareils.

   L'utilisation du Tableau T.8 et du Tableau T.9 comme guide pour le choix des dimensions de conducteur du *BDM/CDM/PDS* peut rendre moins nécessaire de procéder à un essai de température sur le fil. Les dimensions de conducteur pour d'autres applications (charge calorifique, par exemple) font l'objet d'un examen.

Tableau T.8 – courant permanent admissible des conducteurs en cuivre isolés à l'intérieur d'*enveloppes* d'équipement de commande industriel (en fonction d'une *température ambiante* de 40 °C)

Dimension du conducteur AWG ou kcmil	**Conducteurs avec *isolation* à 90 °C**		**Conducteurs avec *isolation* à 105 °C**	
	***Enveloppe* non ventilée**	**Ouvert ou dans une *enveloppe* ventilée**	***Enveloppe* non ventilée**	**Ouvert ou dans une *enveloppe* ventilée**
24 22 20	1 2 3	2 3 4	1 2 3	2 3 4
18 16 14	4 6 9	6 9 13	4 6 10	6 9 15
12 10 8	12 18 31	17 27 47	15 22 35	22 35 55
6 4 3	45 61 70	67 91 104	52 71 80	80 108 121
2 1 0	80 94 110	120 141 164	90 107 133	140 164 190
00 000 0000	128 148 173	191 221 258	148 171 200	221 257 300
250 300 350 400 500	194 214 242 262 298	285 322 355 385 442	221 250 276 299 343	340 384 420 449 515

Tableau T.9 – Facteurs de correction du courant permanent admissible pour plusieurs groupes de conducteurs

Nombre de conducteurs	Facteur de correction
1 à 3	1,00
4 à 6	0,80
7 à 24	0,70
25 à 42	0,60
43 et plus	0,50

2) Des conducteurs plus petits que No. 24 AWG peuvent être utilisés pour le câblage des cartes de circuit imprimé et le câblage d'interconnexion entre des modules électroniques et des sous-ensembles.
3) Les espaces pour câblage externe doivent présenter, en étant libres de tout obstacle, une section égale à au moins 250 % de la section totale du nombre maximal de fils destinés à être installés à l'intérieur, la largeur ou la profondeur maximale ne devant pas être inférieure aux valeurs indiquées dans le Tableau T.10.

Tableau T.10 – Espace de câblage

Dimension de fil maximale AWG/kcmil	**Largeur ou profondeur minimales de l'espace de câblage** mm
10 et plus petit	Non spécifié
8	12
6	15
4	19
3	19
2	22
1	25
0	25
00	25
000	28
0000	31
250	34
300	38
350	38
400	41
500	44
600	47
700	50
750	50
800	54
900	57
1 000	57
1 250	63
1 500	70
1 750	73
2 000	79

4) Les dimensions de fil spécifiées dans le Tableau T.11 et dans le Tableau T.14 doivent être déterminées comme suit.

   a) Pour les *BDM/CDM/PDS* assignés en cheval-vapeur,

      i) le courant de fonctionnement du moteur à pleine charge doit être choisi dans le Tableau T.12 ou le Tableau T.13,

      ii) le courant permanent admissible du conducteur doit être choisi dans le tableau correspondant du Canadian Electrical Code, Part I, et

      iii) la dimension de fil avec un courant permanent admissible à 75 °C doit être choisie dans le Tableau 2 ou le Tableau 4 du Canadian Electrical Code, Part I.

   b) Pour les *BDM/CDM/PDS* assignés en ampères, le courant permanent admissible du conducteur et la dimension de fil doivent être choisis selon T.4.11.1 4) ii) et T.4.11.1 4) iii).

   c) Pour les *BDM/CDM/PDS* assignés en ampères, la dimension de fil doit être choisie selon T.4.11.1 4) iii).

Tableau T.11 – Espace de courbure des fils

Dimension de fil AWG/kcmil	**Distance minimale** mm			
	Nombre de fils par borne			
	1	**2**	**3**	**4 ou plus**
10 et plus petit	Non spécifié	—	—	—
8	38	—	—	—
6	38	—	—	—
4	50	—	—	—
3	50	—	—	—
2	63	—	—	—
1	76	—	—	—
0	127	127	178	—
00	152	152	190	—
000	165 (152)	165 (152)	203	—
0000	177 (152)	177 (152)	216 (203)	—
250	203 (165)	203 (165)	228 (203)	254
300	254 (177)	254 (203)	279 (254)	304
350	305 (228)	305 (228)	330 (254)	355 (304)
400	305 (254)	305 (254)	355 (279)	381 (304)
500	305 (279)	305 (279)	355 (305)	406 (330)
600	355 (305)	406 (330)	457 (381)	482 (406)
700	355 (330)	406 (381)	457 (432)	482 (457)
750	457 (355)	482 (406)	558 (482)	609 (533)
800	457	482	558	609
900	457	482	609	609
1 000	508	—	—	—
1 250	558	—	—	—
1 500 à 2 000	609	—	—	—

Tableau T.12 – Courants de fonctionnement du moteur à pleine charge, en ampères, correspondant aux caractéristiques assignées de cheval-vapeur en courant alternatif

Cheval-vapeur	110 V à 120 V			220 V à 240 V[a]			440 V à 480 V			550 V à 600 V		
	Mono phasé	Bi phasé	Tri phasé	Mono phasé	Bi phasé	Tri phasé	Single-phase	Bi phasé	Tri phasé	Mono phasé	Bi phasé	Tri phasé
1/10	3	—	—	1,5	—	—	—	—	—	—	—	—
1/8	3,8	—	—	1,9	—	—	—	—	—	—	—	—
1/6	4,4	—	—	2,2	—	—	—	—	—	—	—	—
1/4	5,8	—	—	2,9	—	—	—	—	—	—	—	—
1/3	7,2	—	—	3,6	—	—	—	—	—	—	—	—
1/2	9,8	4	4.4	4,9	2	2,2	2,5	1	1	2	0.8	0,9
3/4	13,8	4,8	6.4	6,9	2,4	3,2	3,5	1,2	1,4	2,8	1	1,3
1	16	6,4	8.4	8	3,2	4,2	4	1,6	1,8	3,2	1,3	1,7
1-1/2	20	9	12	10	4,5	6,0	5	2,3	2,6	4	1,8	2,4
2	24	11,8	13.6	12	5,9	6,8	6	3	3,4	4,8	2,4	2,7
3	34	16,6	19,2	17	8,3	9,6	8,5	4,2	4,8	6,8	3,3	3,9
5	56	26,4	30,4	28	13,2	15,2	14	6,6	7,6	11,2	5,3	6,1
7-1/2	80	38	44	40	19	22	21	9	11	16	8	9
10	100	48	56	50	24	28	26	12	14	20	10	11
15	135	72	84	—	36	42	34	18	21	27	14	17
20	—	94	108	—	47	54	44	23	27	35	19	22
25	—	118	136	—	59	68	55	29	34	44	24	27
30	—	138	160	—	69	80	68	35	40	54	28	32
40	—	180	208	—	90	104	88	45	52	70	36	41
50	—	226	260	—	113	130	108	56	65	86	45	52
60	—	—	—	—	133	154	—	67	77	—	53	62
75	—	—	—	—	166	192	—	83	96	—	66	77
100	—	—	—	—	218	248	—	109	124	—	87	99
125	—	—	—	—	—	312	—	135	156	—	108	125
150	—	—	—	—	—	360	—	156	180	—	125	144
200	—	—	—	—	—	480	—	208	240	—	167	192
250	—	—	—	—	—	604	—	—	302	—	—	242
300	—	—	—	—	—	722	—	—	361	—	—	289
350	—	—	—	—	—	828	—	—	414	—	—	336
400	—	—	—	—	—	954	—	—	477	—	—	382
450	—	—	—	—	—	1 030	—	—	515	—	—	412
500	—	—	—	—	—	1 180	—	—	590	—	—	472

[a] Pour obtenir les courants à pleine charge pour des moteurs de 200 V et de 208 V, augmenter les caractéristiques assignées entre 220 V et 240 V correspondantes de 15 % et 10 %, respectivement.

Tableau T.13 – Courants de fonctionnement du moteur à pleine charge, en ampères, correspondant aux caractéristiques assignées de cheval-vapeur en courant continu

Cheval-vapeur	90 V	110 V à 120 V	180 V	220 V à 240 V	500 V	550 V à 600 V
1/10	—	2,0	—	1,0	—	—
1/8	—	2,2	—	1,1	—	—
1/6	—	2,4	—	1,2	—	—
1/4[a]	4,0	3,1	2,0	1,6	—	—
1/3	5,2	4,1	2,6	2,0	—	—
1/2	6,8	5,4	3,4	2,7	—	—
3/4	9,6	7,6	4,8	3,8	—	1,6
1	12,2	9,5	6,1	4,7	—	2,0
1-1/2	—	13,2	8,3	6,6	—	2,7
2	—	17,0	10,8	8,5	—	3,6
3	—	25,0	16,0	12,2	—	5,2
5	—	40,0	27,0	20,0	—	8,3
7-1/2	—	58,0	—	29,0	13,6	12,2
10	—	76,0	—	38,0	18,0	16,0
15	—	110,0	—	55,0	27,0	24,0
20	—	148,0	—	72,0	34,0	31,0
25	—	184,0	—	89,0	43,0	38,0
30	—	220,0	—	106,0	51,0	46,0
40	—	292,0	—	140,0	67,0	61,0
50	—	360,0	—	173,0	83,0	75,0
60	—	—	—	206,0	99,0	90,0
75	—	—	—	255,0	123,0	111,0
100	—	—	—	341,0	164,0	148,0
125	—	—	—	425,0	205,0	185,0
150	—	—	—	506,0	246,0	222,0
200	—	—	—	675,0	330,0	294,0
[a] Le courant à pleine charge pour un moteur 1/4 hp, 32 V en courant continu est de 8,6 A						

T.4.11.2 *Isolation* des conducteurs

T.4.11.2.1 Généralités

Ajout à 4.11.2.1:

1) Si des bus de raccordement et des joints de bus isolants sont fournis, ils doivent satisfaire aux exigences suivantes.
   a) Les joints de bus, autres que les joints de transport, doivent être complètement recouverts d'un matériau isolant en usine. Pour les joints de barre de permutation qui doivent être fabriqués sur le terrain, un matériau isolant doit être fourni pour l'application conformément aux instructions du fabricant.
   b) Un échantillon représentatif de bus isolé doit résister sans claquage à l'essai d'*isolation* de bus de raccordement spécifié en T.4.11.2 c) et d). Cet essai doit être réalisé sur un échantillon d'essai de bus de raccordement isolé pour chaque tension assignée.

c) L'échantillon de bus de raccordement isolé doit présenter la tension assignée maximale à la fréquence industrielle assignée appliquée entre le conducteur et une électrode couvrant effectivement la surface externe de l'*isolation*, mais étant suffisamment éloignée des extrémités de l'échantillon pour pouvoir résister à la tension d'essai.

d) La construction de l'échantillon de bus de raccordement isolé doit être classique des bus de raccordements, des coudes, des épissures et joints utilisés dans la conception du fabricant. La tension d'essai doit être appliquée pendant 1 min.

NOTE Les électrodes externes suggérées sont une peinture conductrice, une feuille métallique, ou un équivalent. Il convient de veiller à empêcher le support d'*isolation* externe de pénétrer dans la zone d'essai entre l'*isolation* de l'échantillon et les électrodes.

T.4.11.2.2 Généralités

T.4.11.2.3 Système de *câblage* accessible

Modification du 4.11.2.2:

L'IEC 61084 (toutes les parties) et l'IEC 61386 (toutes les parties) ne sont pas applicables.

T.4.11.3 Fil multibrin

T.4.11.4 Cheminement et serrage

Ajout à 4.11.4:

1) Les fils doivent être soutenus, fixés ou acheminés dans des chemins de câbles appropriés, de manière à ne pas entrer en contact avec des parties mobiles ou à reposer sur des bords aiguisés ou des projections qui peuvent provoquer l'abrasion de l'*isolation*. Les fils doivent être souples ou extra souples lorsqu'ils assurent la connexion à l'équipement électrique monté sur une *porte* battante. Si la partie en courbure du câblage est susceptible d'entrer en contact avec les parties métalliques reliées à la terre, elle doit faire l'objet d'une protection supplémentaire avec des enroulements de bande, ou un équivalent, ou doit être intégrée dans une gaine ou un tuyau souple non métallique.

2) Un fil soumis à une courbure à l'ouverture d'une *porte* doit

   a) être toronné et, s'il dépasse 6 AWG, doit comporter des conducteurs en cuivre de type extra souple, et

   b) être câblé, acheminé, fixé et protégé de manière à ne pas être endommagé lors de l'ouverture et de la fermeture de la *porte*.

3) Si des conducteurs supérieurs à No. 10 AWG d'un circuit à courant alternatif traversent une paroi métallique ou une cloison ayant des propriétés magnétiques, la totalité des conducteurs du circuit, y compris le neutre, doivent passer par la même ouverture. Les conducteurs peuvent traverser des ouvertures dans une paroi ou une cloison en métal ayant des propriétés magnétiques si

   a) les ouvertures sont reliées par des fentes découpées dans la paroi métallique, ou

   b) pendant l'essai de température du S.5.2.3.10, les températures sont relevées sur un métal intercalé afin de déterminer que l'*isolation* du conducteur n'est pas altérée. Les conducteurs peuvent passer par les ouvertures individuelles d'un bloc isolant utilisé pour *recouvrir* une ouverture dans la paroi métallique, ces ouvertures étant suffisamment larges pour tous les conducteurs du circuit si aucun support, appui ou élément analogue n'est placé sur le matériau isolant entre les conducteurs. Voir la Figure T.1.

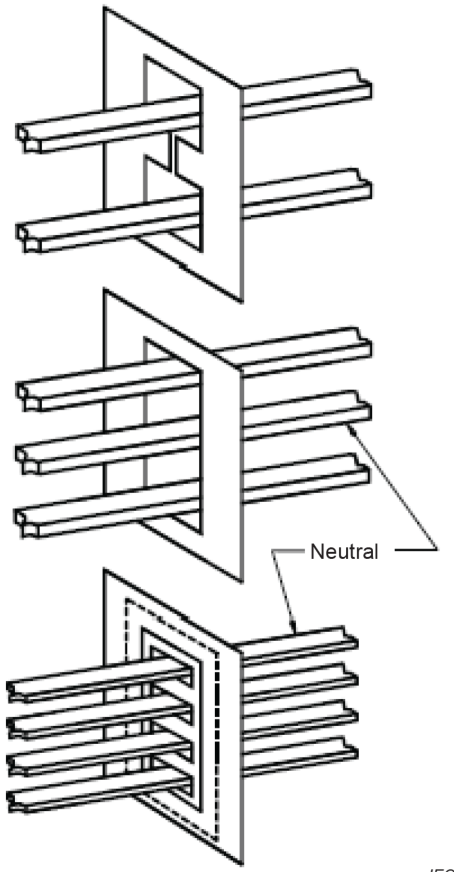


Figure T.1 – Acheminement des conducteurs à travers une barrière métallique

Tableau T.14 – Espace de courbure des fils

Dimension de fil AWG/kcmil	**Distance minimale** mm				
	Nombre de fils par borne				
	1	**2**	**3**	**4**	**5**
14 à 10	Non spécifié				
8 à 6	38	—	—	—	—
4 à 3	50	—	—	—	—
2	63	—	—	—	—
1	76	—	—	—	—
0 à 00	88	127	177	—	—
000 à 0000	101	152	203	—	—
250	114	152	203	254	—
300 à 350	127	203	254	304	—
400 à 500	152	203	254	304	355
600 à 700	203	254	304	355	406
750 à 900	203	304	355	406	457
1 000 à 1 250	254	—	—	—	—
1 500 à 2 000	304	—	—	—	—

T.4.11.5 Identification des conducteurs et des bornes *du réseau* et *de l'alimentation non raccordée directement au réseau*

Modification du 4.11.5:

L'identification des conducteurs et des bornes pour la *liaison équipotentielle de protection* et des *conducteurs de mise à la terre de protection*, y compris, entre autres, leur couleur et leurs symboles, doivent être conformes à la CSA C22.2 No. 0.4.

T.4.11.6 Épissures et raccordements

T.4.11.7 Connexions accessibles

T.4.11.8 Interconnexions entre les parties d'un *PDS*

Modification du 4.11.8:

1) L'IEC 60364 (toutes les parties) ne s'applique pas et est remplacée par la CSA C22.1 CE code, Part I;
2) L'IEC 60204-1:2016 ne s'applique pas et est remplacée par la CSA C22.2 No.14 et la CSA C22.2 No.301.

T.4.11.9 Raccordement de l'alimentation *pour les BDM/CDM/PDS connectés en permanence*

Ajout d'un paragraphe supplémentaire à 4.11.9:

T.4.11.9.200 Raccordement de l'alimentation

1) Un *BDM/CDM/PDS* doit comporter des moyens de connexion au *système* de câblage applicable conformément aux exigences du Canadian Electrical Code, Part I.
2) Un trou taraudé permettant de fixer un conduit rigide fileté doit satisfaire aux exigences de la CSA C22.2 No. 0.5.
3) Les ouvertures défonçables doivent satisfaire aux exigences de la CSA C22.2 No. 0.
4) À l'exception de ce qui est prévu en T.4.11.200, le *BDM/CDM/PDS* doit être équipé de bornes de câblage ou de fils permettant d'assurer la connexion des conducteurs avec un courant permanent admissible qui n'est pas inférieur à la valeur la plus importante parmi les suivantes:
   a) la valeur assignée en ampère du dispositif;
   b) 125 % du courant de fonctionnement du moteur à pleine charge spécifié dans le Tableau T.12 ou dans le Tableau T.13 pour les caractéristiques assignées de cheval-vapeur;
   c) 125 % de la valeur assignée en ampère résistive des dispositifs destinés à commander les charges des équipements électriques fixes de chauffage des locaux; ou
   d) 135 % du courant nominal capacitif des dispositifs destinés à commuter les condensateurs pour la correction du facteur de puissance.
5) Un *BDM/CDM/PDS* avec un courant nominal ou une caractéristique assignée de cheval-vapeur avec un courant de fonctionnement du moteur à pleine charge, comme cela est spécifié dans le Tableau T.12 ou dans le Tableau T.13, doit être relié avec un fil d'une dimension déterminée conformément au Tableau 2 du Canadian Electrical Code, Part I. La dimension doit dépendre du fil adapté à une température de 60 °C pour une caractéristique assignée maximale de 100 A et d'un fil adapté à une température de 75 °C pour une caractéristique assignée supérieure à 100 A. Le type d'*isolation* n'est pas spécifié.
6) Un fil destiné à être épissé sur le terrain sur un conducteur de circuit ne doit pas être inférieur à No. 18 AWG. L'épaisseur d'une *isolation* en caoutchouc ou thermoplastique ne doit pas être inférieure à 0,8 mm.

T.4.11.10 Raccordement de l'alimentation des *BDM/CDM/PDS* enfichables

T.4.11.11 Bornes

T.4.11.11.1 Exigences de construction

Ajout à 4.11.11.1:

1) Les parties de borne pour le câblage externe doivent satisfaire aux exigences de la CSA C22.2 No. 0, sauf que
   a) les têtes de vis de serrage, boulons, goujons, écrous et rondelles ferreux peuvent être utilisés s'ils sont correctement protégés par un revêtement en zinc ou un matériau équivalent d'au moins 0,005 mm d'épaisseur, et
   b) pour un conducteur No. 10 AWG ou plus petit, la borne à laquelle les raccordements sont réalisés peut être composée d'étriers ou de vis de serrage dont une plaque à bornes comporte des cosses retournées, ou un équivalent, pour maintenir les fils en position.

   Voir le Tableau T.15 pour les exigences relatives à la borne.
2) Une vis de serrage à laquelle le câblage externe est réalisé ne doit pas être inférieure à No. 8. Toutefois, une vis No. 5 peut être utilisée au niveau d'une borne destinée uniquement à la connexion d'un conducteur No. 14 AWG ou plus petit. Une vis No. 6 doit être utilisée au niveau d'une borne destinée uniquement à la connexion d'un conducteur No. 12 AWG ou plus petit.
3) Une plaque à bornes taraudée pour recevoir une vis de serrage doit être en métal d'au moins 0,75 mm d'épaisseur pour un fil No. 14 AWG ou plus petit, et d'au moins 1,25 mm d'épaisseur pour un câble supérieur à No. 14 AWG. La plaque ne doit pas comporter moins de deux filets complets. Toutefois, deux filets complets ne doivent pas être exigés si moins de filets assurent une connexion sécurisée dans laquelle les filets ne s'ébavurent pas sous l'application d'un couple de serrage de 2,3 Nm.
4) Le métal d'une plaque à bornes formée à partir de matières premières et dont l'épaisseur minimale est celle exigée en T.4.11.11.1 3) peut être extrudé au niveau du trou taraudé pour la vis de serrage afin de fournir deux filets complets.
5) Les bornes des résistances utilisées dans les circuits secondaires des moteurs asynchrones à rotor bobiné et dans les circuits d'induit de moteurs shunt en courant continu, doivent être adaptées pour la fixation des conducteurs spécifiés dans le Tableau T.16.
6) L'IEC 60947-7 (toutes les parties) ne s'applique pas, remplacée par la série de normes CSA C22.2 No.60947-7.

Tableau T.15 – Valeurs d'essai des bornes de câblage de *BDM/CDM/PDS*

Dimension du conducteur AWG/kcmil	**Force de traction** N	
	Cuivre	**Aluminium ou aluminium plaqué de cuivre**
22	20	—
20	30	—
18	30	—
16	40	—
14	50	—
12	60	44
10	80	44
8	90	44
6	94	124
4	133	160
3	156	187
2	186	222
1	236	271
0	285	320
00	285	347
000	351	432
0000	427	516
250	427	516
300	441	516
350	503	574
400	503	574
500	578	685
600	578	685
700	645	796
800	690	796
900	702	805
1 000	778	885
1 250	985	1 116
1 500	1 174	1 343
1 750	1 347	1 521
2 000	1 521	1 699

Tableau T.16 – Courant permanent admissible des conducteurs en fonction des caractéristiques assignées de cycle de service de la résistance

Cycle de service	N° de classification[b, c] de la résistance[b, c]	Courant permanent admissible des conducteurs en pourcentage des courants d'induit ou secondaires à pleine charge
5 s ON 75 s OFF	101 à 106 111 à 116	35
10 s ON 70 s OFF	131 à 136	45
15 s ON 75 s OFF	141 à 146	55
15 s ON 45 s OFF	151 à 156 151P à 154P 152DL et 153 DL	65
15 s ON 30 s OFF	161 à 166 161P à 164P 162DL et 163DL	75
15 s ON 15 s OFF	171 à 176 171P à 174P 172DL et 173DL	90
Service continu	91 à 96 91P à 94P 92DL et 93DL	110

[a] Issu de l'EEMAC E14-2, Part ICS2-213, "Resistors and Rheostats".

[b] Les numéros de classification qui incluent la lettre "P" concernent le service d'obturation, les lettres "DL" concernant l'abaissement dynamique.

[c] Les numéros de classification peuvent être suivis du suffixe "AS" pour le shunt d'induit (Armature Shunt) ou "DB" pour la résistance de freinage dynamique (Dynamic braking).

T.4.11.11.1 Exigences de construction

T.4.11.11.2 Capacité de raccordement des bornes

Remplacement du 4.11.11.2 par T.4.11.9.200 4).

T.4.11.11.3 Raccordement à des conducteurs externes

T.4.11.11.4 Espace de courbure des câbles de 10 mm2

Ajout à 4.11.11.4:

L'espace de courbure des fils au niveau des *bornes pour câblage externe* des *BDM/CDM/PDS* sous enveloppe assignés à 750 V au maximum doit satisfaire aux exigences suivantes, selon le cas.

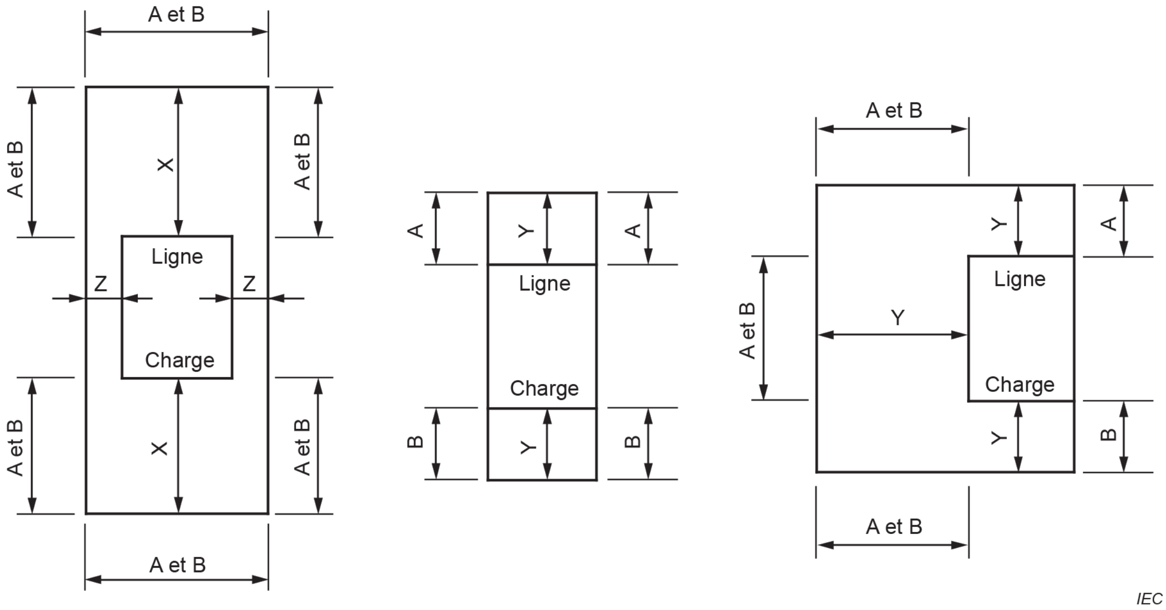
S'il est prévu qu'un conducteur entre dans l'*enveloppe* ou en sorte en passant par la paroi opposée à la borne ou qu'il traverse une barrière ou un autre obstacle, la distance ne doit pas être inférieure à celle spécifiée dans le Tableau T.11.

S'il est prévu qu'un conducteur n'entre pas dans l'*enveloppe* ou n'en sorte pas en passant par la paroi opposée à la borne, et que le conducteur est soumis à une flexion par la paroi, une barrière ou un autre obstacle, la distance ne doit pas être inférieure à celle spécifiée dans le Tableau T.14.

Ajout d'un paragraphe supplémentaire à 4.11.11.4:

T.4.11.11.4.200 Espace de courbure des fils (informative)

La Figure T.2 donne des exemples d'application des exigences spécifiées dans le présent document.



Légende

X espace de courbure des fils selon le Tableau T.11

Y espace de courbure des fils selon le Tableau T.14

Z espace de câblage selon le Tableau T.10

A section du périmètre de l'*enveloppe* dans laquelle les fils du *réseau* peuvent entrer

B section du périmètre de l'*enveloppe* dans laquelle les fils de charge peuvent entrer

Figure T.2 – Espace de courbure des fils

T.4.11.12 Dispositions en matière de connexion du blindage du fil ou du câble blindé

Ajout d'un paragraphe supplémentaire à 4.11:

T.4.11.200 *Accessoires* et kits installés sur le terrain

1) Généralités

   a) L'Article T.4.11.200 doit s'appliquer aux *accessoires* conçus pour une installation sur le terrain dans le *BDM/CDM/PDS*.

   b) L'Article T.4.11.200 doit également s'appliquer, selon le cas, à l'installation sur le terrain des *accessoires* dans le *BDM/CDM/PDS*.

2) Kits de serre-fils et kits de mise à la terre

   a) Il n'est pas nécessaire que les *BDM/CDM/PDS* destinés à être terminés par un câblage externe supérieur au No. 10 AWG comportent des connecteurs si un connecteur et des kits de mise à la terre qui s'adaptent correctement aux conducteurs correspondant à la valeur assignée en ampère du dispositif sont mis à disposition par le fabricant du *BDM/CDM/PDS*. Des kits de mise à la terre peuvent être fournis pour toutes les dimensions de conducteurs.

b) Les kits de serre-fils et kits de mise à la terre (sous la forme de bornes individuelles ou d'un ensemble) doivent être construits de sorte que

   i) l'installation puisse être aisément réalisée sans l'aide d'outils spéciaux,

   ii) les *parties actives* soient correctement soutenues après leur assemblage,

   iii) des connexions fiables aux plaquettes de borne soient possibles,

   iv) les moyens de borne de terre soient aisément accessibles lorsque le *BDM/CDM/PDS* est monté comme en service et ne soient pas reliés directement à un neutre (s'il est fourni),

   v) chaque kit puisse être installé sans démonter les parties montées en usine (autres que celles normalement montées pour l'installation et le câblage), et

   vi) les *distances d'isolement* et *lignes de fuite* soient maintenues lorsque le kit est installé.

3) Autres kits

   a) Le *BDM/CDM/PDS* doit être adapté à une utilisation avec et sans ce type de kit.

   b) Chaque kit doit être acceptable pour l'utilisation prévue et, lorsqu'il est installé comme prévu, doit satisfaire à toutes les exigences applicables du présent document.

   c) Chaque kit doit pouvoir être installé sans l'aide d'un outil spécial, sauf si ce type d'outil et ses instructions d'utilisation sont fournis avec chaque kit.

   d) Une barrière qui est nécessaire, les *distances d'isolement* et *lignes de fuite* étant sinon inférieurs à ceux exigés ou pour toute autre raison, doit être fermement fixée au kit ou au *BDM/CDM/PDS*.

4) Les marquages apposés sur les kits doivent être tels que décrits en T.6.2.2.200.

T.4.12 Exigences mécaniques pour *les enveloppes*

T.4.12.1 Généralités

Remplacement du 4.12.1:

1) Les *enveloppes* doivent être adaptées à une utilisation dans leurs environnements prévus. Le fabricant doit spécifier la caractéristique assignée de type de l'*enveloppe* selon les exigences de la CSA C22.2 No. 94.2. Le fabricant peut ajouter une désignation IP supplémentaire à la désignation de type exigée, conformément aux spécifications de la CSA C22.2 No. 60529.

2) Les *BDM/CDM/PDS* fournis avec et installés dans des *enveloppes* à entrée libre doivent satisfaire aux exigences en matière de distance de travail du Canadian Electrical Code, Part I. Les *BDM/CDM/PDS* avec des *enveloppes* complètes ou partielles doivent être évalués comme des dispositifs ouverts conformément aux exigences de performances du présent document.

3) Des dispositions pour le montage doivent être prises pour assurer un montage en toute sécurité du *BDM/CDM/PDS* sur une surface de support. Un boulon, une vis ou une autre pièce utilisée pour monter un *composant* du *BDM/CDM/PDS* ne doit pas être utilisé(e) pour fixer le dispositif complet à la surface de support. Les dispositifs montés sur panneau qui peuvent être manipulés dans des conditions normales de fonctionnement (des commutateurs et des rhéostats, par exemple) doivent être agrafés ou empêchés de pivoter. Ces dispositifs qui font uniquement appel au frottement ne doivent pas être considérés comme étant acceptables.

4) Outre les *BDM/CDM/PDS* conçus pour être posés librement, des dispositions doivent être prises pour assurer un montage en toute sécurité du *BDM/CDM/PDS* sur une surface de support.

5) Des revêtements peuvent être omis depuis le fond d'une *enveloppe* posée au sol de type 1, 2 ou 3R si
   a) l'*enveloppe* s'étend sur le sol, les *parties actives* étant montées dans l'*enveloppe* selon 4.4.7.4 et 4.4.7.5,
   b) le *BDM/CDM/PDS* est assigné à 750 V au maximum,
   c) l'*enveloppe* est dans les limites de 150 mm du sol, et
   d) les *parties actives* nues du dispositif ne sont pas à moins de 150 mm au-dessus du bord inférieur de l'*enveloppe.*

T.4.12.2 Poignées et commandes manuelles

T.4.12.3 Enveloppe en *métal* coulé

Remplacement du 4.12.3:

Une *enveloppe* en métal coulé de fonte malléable et de métal coulé ou en aluminium, laiton, bronze ou zinc coulé en coquille doit présenter une épaisseur minimale

a) de 2,4 mm pour une surface supérieure à 15 500 mm² ou dont l'une des dimensions est supérieure à 150 mm;
b) de 1,6 mm pour une surface inférieure ou égale à 15 500 mm² et dont aucune dimension n'est supérieure à 150 mm. La surface peut être délimitée par des nervures de renforcement qui subdivisent une plus grande surface; et
c) de 3,2 mm au niveau des nervures de renforcement, des bords de *porte* et des entrées de conduit non filetées.

Les épaisseurs peuvent être réduites si l'*enveloppe* satisfait aux exigences des essais de choc et de connexion du conduit du 5.2.2.4.3 et T.5.2.2.200 1).

T.4.12.4 Enveloppe en *tôle*

Remplacement du Tableau 22 et du Tableau 23 par le Tableau T.17 et le Tableau T.18.

Ajout à 4.12.4:

Il n'est pas nécessaire que l'épaisseur de tôle des *enveloppes* aux points autres que ceux où doit être raccordé le *système* de câblage satisfasse aux exigences d'épaisseur du 4.12.4 si l'*enveloppe* satisfait aux exigences du T.5.2.2.4.2 et du T.5.2.2.202.

Tableau T.17 – Épaisseur de tôle des *enveloppes* – Acier au carbone ou acier inoxydable

Sans châssis support[a] cm		Avec châssis support ou armature équivalente[a] cm		Épaisseur minimale acceptable mm	
Largeur maximale[b]	**Longueur maximale[c]**	**Largeur maximale[b]**	**Longueur maximale[c]**	**Non revêtu**	**Revêtu d'une couche métallique**
10,2 12,1	Non limitée 14,6	15,9 17,1	Non limitée 21,0	0,52	0,59
15,2 17,8	Non limitée 22,2	24,1 25,4	Non limitée 31,8	0,68	0,75
20,3 22,9	Non limitée 29,2	30,5 33,0	Non limitée 40,6	0,78	0,88
31,8 35,6	Non limitée 45,7	49,5 53,3	Non limitée 63,5	1,02	1,16
45,7 50,8	Non limitée 63,5	68,6 73,7	Non limitée 91,4	1,34	1,43
55,9 63,5	Non limitée 78,7	83,8 88,9	Non limitée 109,2	1,52	1,62
63,5 73,7	Non limitée 91,4	99,1 104,1	Non limitée 129,5	1,69	1,79
83,8 96,5	Non limitée 119,4	129,5 137,2	Non limitée 167,6	2,00	2,14
10,7 119,4	Non limitée 149,9	162,6 172,7	Non limitée 213,4	2,30	2,47
132,1 152,4	Non limitée 188,0	203,2 213,4	Non limitée 261,6	2,73	2,85
160,0 185,4	Non limitée 228,6	246,4 261,6	Non limitée 322,6	3,11	3,23

[a] Voir 4.12.4.

[b] La largeur représente la plus petite cote d'une pièce rectangulaire en tôle faisant partie d'une *enveloppe*. Les surfaces voisines d'une *enveloppe* peuvent avoir des supports communs et n'être constituées que d'une seule feuille de tôle.

[c] "Non limité" ne s'applique que si la surface possède un bord tombé d'au moins 12,7 mm ou lorsqu'elle est fixée aux surfaces voisines qui ne sont normalement pas démontées en cours d'utilisation.

Tableau T.18 – Épaisseur de tôle des *enveloppes* – Aluminium, cuivre ou laiton

Sans châssis support[a] cm		Avec châssis support ou armature équivalente[a] cm		Épaisseur minimale acceptable mm
Largeur maximale[b]	Longueur maximale[c]	Largeur maximale[b]	Longueur maximale[c]	
7,6 8,9	Non limitée 10,2	17,8 21,6	Non limitée 24,1	0,58
10,2 12,7	Non limitée 15,2	25,4 26,7	Non limitée 34,3	0,74
15,2 16,5	Non limitée 20,3	35,6 38,1	Non limitée 45,7	0,91
20,3 24,1	Non limitée 29,2	48,3 53,3	Non limitée 63,5	1,14
30,5 35,6	Non limitée 40,6	71,1 76,2	Non limitée 94,0	1,47
45,7 50,8	Non limitée 63,4	106,7 114,3	Non limitée 139,7	1,91
63,5 73,7	Non limitée 91,4	152,4 162,6	Non limitée 198,1	2,41
94,0 106,7	Non limitée 134,6	221,0 236,2	Non limitée 289,6	3,10
132,1 152,4	Non limitée 188,0	312,4 330,2	Non limitée 406,4	3,89

[a] Voir 4.12.4.

[b] La largeur représente la plus petite cote d'une pièce rectangulaire en tôle faisant partie d'une *enveloppe*. Les surfaces voisines d'une *enveloppe* peuvent avoir des supports communs et n'être constituées que d'une seule feuille de tôle.

[c] "Non limitée" ne s'applique que si la surface possède un bord tombé d'au moins 12,7 mm ou lorsqu'elle est fixée aux surfaces voisines qui ne sont normalement pas démontées en cours d'utilisation.

T.4.12.5 Stabilité des BDM/*CDM/PDS posés* au sol

T.4.12.6 Support d'attache de câbles

T.4.12.7 Détente *des* contraintes d'une *enveloppe* polymère

T.4.12.8 Condensation interne ou accumulation d'eau

T.4.12.9 Résistance aux ultraviolets (UV) d'une *enveloppe* polymère à usage extérieur

Modification du 4.12.9:

L'*enveloppe* à usage extérieur doit satisfaire aux exigences de la CSA C22.2 No. 94.2.

Ajout de paragraphes supplémentaires à 4.12:

T.4.12.200 *Portes*, *capots* et parties similaires des *enveloppes*

1) À l'exception de ce qui est indiqué en T.4.12.200 2), une partie de l'*enveloppe* (une *porte*, un *capot* ou une cuve, par exemple) doit être équipée de moyens (loquets, *verrouillages* ou vis, par exemple) de la maintenir fermement en place. Si des *parties actives* nues sont exposées après l'ouverture de ces portes ou *capots*, des moyens exigeant l'utilisation d'un outil pour les ouvrir ou des dispositions permettant de les verrouiller doivent être prévus pour les maintenir en position fermée.

2) Un *capot* à pression donnant accès aux *parties actives* nues et sans fixation séparée maniée par un outil (comme cela est décrit en T.4.12.200 1)) doit être acceptable, à condition qu'il ne comporte aucun moyen apparent permettant de le retirer (une languette, par exemple) et qu'il résiste à l'essai de fixation spécifié en T.5.2.2.201.

3) Les *enveloppes* dont il est exigé qu'elles soient ouvertes dans des conditions normales de fonctionnement, les *parties actives* étant alors exposées, doivent être équipées

   a) de *portes* battantes montées de sorte qu'elles ne soient pas ouvertes par inadvertance, et

   b) de barrières installées de manière à empêcher tout contact avec les *parties actives* nues dans des conditions normales de fonctionnement.

   NOTE Le remplacement des fusibles n'est pas considéré comme une condition normale de fonctionnement du *BDM/CDM/PDS*, à l'inverse du réarmement des dispositifs de protection contre les surcharges, du réglage répété des temporisateurs ou des commutateurs, etc.

4) Un *capot* à charnière, fourni selon les exigences du T.4.12.200 3), doit être prévu avec un loquet ou verrou à ressort ou avec une fixation captive. Ces fixations doivent être placées ou utilisées à plusieurs endroits, de manière à maintenir le *capot* fermé sur toute sa longueur. Un *capot* à charnière de plus de 1 220 mm sur le bord battant doit comporter au moins un loquet à deux points actionné par un seul bouton ou une seule manette ou doit avoir au moins deux loquets à ressort ou fixations captives distinct(e)s.

T.4.12.201 Ouvertures dans les *enveloppes*

1) Une *enveloppe*, lorsqu'elle est installée, ne doit comporter aucune ouverture (autres que celles prévues pour la ventilation) permettant l'entrée d'une tige de diamètre supérieur à 12,7 mm. Ces types d'ouvertures doivent satisfaire aux exigences suivantes.

2) La dimension ou la forme des ouvertures de ventilation d'une *enveloppe* d'un *BDM/CDM/PDS* assigné à 1 500 V au maximum (y compris les perforations, les grilles de transfert et les ouvertures protégées par un écran en toile métallique, du métal déployé ou un *capot* perforé) ne doivent pas permettre l'entrée d'une tige de diamètre supérieur à 19 mm pour les circuits de 600 V au maximum et de 12,7 mm pour les circuits de 601 V à 1 500 V. L'ouverture doit également satisfaire aux exigences du T.4.12.201 4), 5) et 6).

3) Pour les *BDM/CDM/PDS* assignés à plus de 750 V, ce qui suit doit s'appliquer:

   a) Les ouvertures de ventilation (y compris les perforations, les grilles de transfert et les ouvertures) doivent être protégées par un écran en toile métallique, du métal déployé ou un *capot* perforé qui ne doit pas permettre l'entrée de la tige comme cela est spécifié en T.4.11.200.

   b) Des barrières doivent être prévues derrière toutes les ouvertures de ventilation dans les compartiments *haute tension*. La barrière doit être solidement fixée et doit masquer les *parties actives*.

   c) Le diamètre des fils d'un écran doit être d'au moins 1,3 mm si la surface maximale des ouvertures de l'écran est de 320 mm^2, et doit être d'au moins 2,06 mm pour des ouvertures d'écran plus importantes.

   d) La tôle d'acier perforée et la tôle d'acier utilisée pour les lattes de métal déployé doivent présenter une épaisseur d'au moins 1,07 mm pour les ouvertures de maille ou les perforations de surface maximale de 320 mm^2, et une épaisseur d'au moins 2,03 mm pour les plus grandes ouvertures.

4) La dimension des ouvertures décrites en T.4.12.201 1), 3) et 4), ou leur emplacement doit empêcher le doigt d'essai articulé présenté à la Figure M.2, d'entrer en contact avec des *parties actives* non *isolées*. Un fil émaillé doit être considéré comme une *partie active* non *isolée*.

5) Le doigt d'essai spécifié en T.4.12.201 4) doit être appliqué dans toutes les configurations possibles, et après son insertion dans l'ouverture, la configuration doit être modifiée si nécessaire.

6) Le doigt d'essai spécifié en T.4.12.201 4) doit uniquement être utilisé comme un instrument de mesure pour évaluer l'accessibilité assurée par l'ouverture. Il ne doit pas être utilisé comme instrument d'évaluation de la résistance d'un matériau. La force d'application du doigt d'essai ne doit pas dépasser 11 N.

7) Le diamètre des fils d'un écran doit être d'au moins 1,3 mm si la surface maximale des ouvertures de l'écran est de 320 mm^2, et doit être d'au moins 2,06 mm pour des ouvertures d'écran plus importantes.

8) La tôle d'acier perforée et la tôle d'acier utilisée pour les lattes de métal déployé doivent présenter une épaisseur d'au moins 1,07 mm pour les ouvertures de maille ou les perforations de surface maximale de 320 mm^2, et une épaisseur d'au moins 2,03 mm pour les plus grandes ouvertures. Dans un dispositif de petite taille dans lequel l'indentation d'un protecteur ou d'une *enveloppe* ne modifie pas la *distance d'isolement* entre les *parties actives* mobiles non isolées et le métal relié à la terre au point de compromettre les performances ou de réduire les *distances d'isolement* et *lignes de fuite* sous les valeurs minimales spécifiées en 4.4.7.4 et en 4.4.7.5, des lattes en acier déployé d'au moins 0,51 mm d'épaisseur peuvent être prévues, à condition que

   a) la surface de la latte déployée sur un côté ou sur la surface du dispositif ainsi protégé ne dépasse pas 46 500 mm² et que ses dimensions ne soient pas supérieures à 305 mm, ou

   b) la largeur d'une ouverture ainsi protégée ne dépasse pas 88 mm.

9) Le verre couvrant une fenêtre d'observation et faisant partie intégrante de l'*enveloppe* doit être fermement fixé de manière à ne pas pouvoir être aisément déplacé en service et doit assurer la protection mécanique des parties sous enveloppe. L'épaisseur du verre couvrant une ouverture de 100 mm maximum dans toutes les dimensions ne doit pas être inférieure à 1,40 mm. L'épaisseur du verre couvrant une ouverture de dimensions inférieures ou égales à 305 mm ne doit pas être inférieure à 2,92 mm. Le verre utilisé pour couvrir des ouvertures plus importantes doit être un verre de sécurité transparent ou avec armure en fils.

10) Les matériaux polymères transparents couvrant une ouverture doivent résister aux essais applicables spécifiés en T.5.2.2.4.200 et T.5.2.5.5.

11) Les équipements électriques doivent être construits de sorte que les particules en fusion ou enflammées ne puissent pas tomber sur la surface sur laquelle ils sont montés ou sur laquelle ils reposent.

12) Nonobstant T.4.12.201 11), les équipements montés au sol peuvent être marqués selon T.6.3.5.200.

13) Un *composant* interne avec une *enveloppe* polymère (un moteur de ventilateur, par exemple) accessible par les ouvertures dans l'*enveloppe* du *BDM/CDM/PDS* selon T.4.6.4.2, doit satisfaire aux essais réalisés sur les *enveloppes* polymères exigés en T.4.12.201 3).

14) Si les ouvertures dans l'*enveloppe* du *BDM/CDM/PDS* exposent un *composant* tel que le corps du moteur de ventilateur (en métal ou en polymère) à l'eau ou à la poussière pendant les essais réalisés selon la CSA-C22.2 No. 94.2, cette *enveloppe* doit protéger le *composant* de cette exposition à l'eau ou à la poussière. L'aptitude de cette *enveloppe* de *composant* à assurer la protection doit être déterminée avec et sans ventilation forcée en fonctionnement.

15) Les *enveloppes* de *BDM/CDM/PDS haute tension* doivent être en métal.

16) Si des parties fonctionnant au-dessus de 750 V sont exposées lorsque les *capots* ou les *portes* sont ouverts, un marquage d'avertissement doit également être fourni conformément à T.4.4.10 1).

17) Les *portes* de compartiments contenant des *composants* haute tension doivent être verrouillées mécaniquement selon T.4.4.10.

18) Les *capots* de compartiments contenant des *composants* haute tension doivent être fermés par des boulons.

19) Si une *porte* doit être ouverte pour la maintenance du *BDM/CDM/PDS* ou la dépose d'éléments de déchargement, les *parties actives* non isolées *basse tension* montées sur la *porte* doivent être correctement protégées ou sous enveloppe afin d'assurer la protection contre tout contact involontaire.

20) Les compartiments *basse tension* qui doivent être ouverts pendant le fonctionnement normal, les *parties actives* étant alors exposées, doivent satisfaire à T.4.12.200 3).

21) Les fenêtres d'observation des contacts isolants doivent être en verre de sécurité transparent ou en verre de sécurité avec armure en fils.

T.4.13 *Composants*

T.4.13.1 *Généralités* sur les *composants*

Ajout à 4.13.1:

À l'exception de ce qui est admis en T.4.1 2), les composants électriques doivent être conformes aux normes applicables du Canadian Electrical Code, Part II, dans la mesure où elles s'appliquent.

T.4.13.2 *Composants* représentant un danger d'incendie

T.4.13.3 *Composants* faisant partie intégrante d'une *enveloppe*

T.4.13.4 *Composants* représentant un danger mécanique

T.4.13.5 Composants *bobinés*

Modification du 4.13.5:

L'IEC 61558-1:2017 ne s'applique pas.

T.4.13.6 Dispositifs de protection

Ajout d'un paragraphe supplémentaire à 4.13.6:

T.4.13.6.200 Protection et porte-fusibles

1) La totalité du câblage entre le côté charge de la protection du circuit de dérivation contre les courts-circuits et le dispositif de protection contre les *surintensités* doit se trouver à l'intérieur de l'*enveloppe* et ne pas mesurer plus de 3 m de longueur.

2) Il n'est pas exigé de prévoir une protection supplémentaire pour un câblage relié à une carte de circuit imprimé totalement intégré dans l'*enveloppe*.

3) Les conducteurs de circuit secondaire alimentés par une alimentation approuvée dont la sortie est par nature limitée doivent être dimensionnés pour le courant de sortie d'alimentation maximal, et il n'est pas exigé par ailleurs de les protéger.

4) Si le *BDM/CDM/PDS* est équipé d'une protection contre les *surintensités*, d'une protection en cas de défaut à la terre et d'une protection contre les surcharges du moteur, il doit être conforme au Canadian Electrical Code, Part I.

5) Les conducteurs de *circuits de commandes* reliés aux côtés charge du *dispositif de protection contre les courts-circuits* du *BDM/CDM/PDS* (commande commune) et qui s'étendent au-delà de l'*enveloppe* de l'équipement de commande, doivent être protégés contre les *surintensités*, en fonction de leurs courants permanents admissibles, par des dispositifs de protection placés à l'intérieur du *BDM/CDM/PDS*. Aucun marquage ou protection supplémentaire n'est exigé si la caractéristique assignée ou le réglage du dispositif de protection prévu du circuit de dérivation du moteur contre les courts-circuits ne dépasse pas 300 % du courant permanent admissible (15 A minimum) des conducteurs du *circuit de commande*.

6) Le pouvoir d'interruption en court-circuit de la protection contre les *surintensités* prévue doit être supérieur ou égal au *courant de court-circuit présumé* du *BDM/CDM/PDS*. Si des fusibles sont fournis, leurs types doivent être ceux admis par la Règle 14-212 du Canadian Electrical Code, Part I.

7) Il n'est pas nécessaire que le dispositif de protection fasse partie intégrante du *BDM/CDM/PDS* si le fabricant met à disposition ou spécifie un kit d'*accessoires* et que le *BDM/CDM/PDS* est marqué selon T.6.2.2.200.

8) Protection du transformateur de *circuit de commande*

   a) À l'exception de ce qui est prévu en T.4.13.6.200 8) b), les enroulements primaire et secondaire du transformateur de *circuit de commande* doivent être protégés par au moins l'un des types suivants de protections contre les *surintensités*:

      i) un ou plusieurs dispositifs de protection contre les *surintensités* individuels placés dans le circuit primaire et assignés ou réglés comme cela est spécifié dans le Tableau T.19. Des dispositifs de protection contre les *surintensités* doivent être prévus dans chaque conducteur non relié à la terre;

      ii) une protection de circuit secondaire assignée ou réglée à 125 % au maximum du courant secondaire assigné du transformateur, la protection du circuit d'alimentation primaire étant assignée ou réglée à 250 % au maximum du courant primaire assigné du transformateur; ou

      iii) une protection coordonnée contre les surcharges thermiques disposée pour interrompre le circuit primaire, à condition que le dispositif de protection contre les *surintensités* du circuit primaire soit assigné ou réglé pour s'ouvrir à un courant maximal de

         – 6 fois le courant assigné du transformateur pour des transformateurs présentant une impédance maximale de 6 %; ou

         – 4 fois le courant assigné du transformateur pour des transformateurs présentant une impédance supérieure à 6 %, mais inférieure à 10 %.

NOTE 1 La caractéristique assignée de 250 % spécifiée en T.4.13.6.200 8) a) ii) ne s'applique pas aux transformateurs dont les entrées de courant primaire assigné sont inférieures à 2 A.

Tableau T.19 – Caractéristique assignée acceptable maximale du dispositif de protection contre les *surintensités* primaire

Courant primaire assigné A	Caractéristique assignée maximale des dispositifs de protection contre les *surintensités* en pourcentage du courant primaire assigné du transformateur
Moins de 2	500
2 à moins de 9	167
9 ou plus	125[a]
[a] Voir T.4.13.6.200 8) c).	

   b) Il n'est pas nécessaire d'assurer la protection contre les *surintensités* si

      i) le transformateur est approuvé comme étant un transformateur à énergie limitée de Classe 2,

      ii) le transformateur est assigné à moins de 50 VA, est protégé par nature, et fait partie intégrante du *BDM/CDM/PDS*,

      iii) le dispositif de protection contre les *surintensités* du circuit d'alimentation primaire assure la protection exigée, ou

      iv) la protection est assurée par d'autres moyens conformes au Canadian Electrical Code, Part I.

c) Si le courant secondaire assigné d'un transformateur est d'au moins 2 A, le courant assigné du dispositif secondaire de protection contre les *surintensités* peut être égal aux valeurs indiquées dans le Tableau T.20.

Si le courant primaire assigné du transformateur est d'au moins 9 A et que 125 % de ce courant ne correspond à aucune caractéristique assignée normalisée du fusible ou du disjoncteur non réglable, la caractéristique assignée normalisée immédiatement supérieure du dispositif de protection doit être utilisée.

Tableau T.20 – Caractéristique assignée acceptable minimale du dispositif de protection contre les *surintensités* secondaire

Courant secondaire assigné A	**Caractéristique assignée maximale des dispositifs de protection contre les *surintensités* en pourcentage du courant secondaire assigné du transformateur**
Moins de 9	167
9 ou plus	125[a]
[a] Voir T.4.13.6.200 8) c).	

d) Un transformateur de commande et ses conducteurs primaire et secondaire peuvent être protégés par des dispositifs de protection contre les *surintensités* situés uniquement dans le circuit primaire, à condition
   i) qu'il s'agisse d'un transformateur monophasé comportant uniquement un secondaire à deux fils (une seule tension),
   ii) que la valeur maximale d'un dispositif de protection contre les *surintensités* prévu soit déterminée selon T.4.13.6.200 Article 8) a), et
   iii) que la valeur maximale d'un dispositif de protection contre les *surintensités* prévu déterminée en T.4.13.6.200 8) d) ii), ne dépasse pas la valeur d'un dispositif de protection contre les *surintensités* obtenue selon le Tableau T.21 pour le conducteur secondaire, multipliée par la tension primaire à secondaire du transformateur.

Tableau T.21 – Protection contre les *surintensités* – Conducteurs en cuivre

Dimension de fil du *circuit de commande* AWG	**Valeur assignée maximale du dispositif de protection** A
22	3
20	5
18	7
16	10
14	20
12	25
10	35

e) Le même dispositif de protection contre les *surintensités* peut être utilisé tant pour la protection du transformateur de circuit de commande que pour la protection du conducteur de circuit primaire lorsque ses caractéristiques assignées satisfont à chaque exigence.

f) Dispositif de protection des transformateurs de commande

   i) À l'exception de ce qui est admis en T.4.13.6.200 8) f) ii), le dispositif de protection spécifié en T.4.13.6.200 6), doit être un dispositif de protection du circuit de dérivation contre les *surintensités*.

   ii) Des dispositifs de protection supplémentaires peuvent être utilisés comme suit.

      1) Des fusibles supplémentaires peuvent être utilisés dans les circuits secondaires des transformateurs de commande à condition que le fusible soit installé dans un porte-fusible et que le contrôleur soit marqué selon 6.4.5.

      2) Un protecteur supplémentaire de type industriel et de protection contre les *surintensités* peut être utilisé dans les circuits secondaires des transformateurs de commande, à condition que la protection primaire du transformateur soit dimensionnée de manière à assurer la protection contre les courts-circuits exigée pour le protecteur supplémentaire, si cela est applicable.

      3) Un protecteur supplémentaire de type industriel et de protection contre les *surintensités* peut être utilisé dans les circuits primaires des transformateurs de commande, à condition que le protecteur supplémentaire comporte

         – un code d'application de court-circuit U3,

         – un code d'application de courant de déclenchement TC3, et

         – un code de surcharge OL1.

g) Protection contre les surcharges du moteur

   i) Le *PDS* doit être équipé d'une protection contre les surcharges pour tous les moteurs faisant partie intégrante du *PDS*, ainsi que le moteur commandé par le *BDM/CDM*, conformément à la Section 28 du Canadian Electrical Code, Part I.

   ii) Le *BDM/CDM/PDS* doit être équipé de l'un des moyens suivants de protection contre les surcharges du moteur:

      – un relais de surcharge mécanique satisfaisant aux exigences de la CSA C22.2 No. 14; ou

      – une protection intégrée contre les surcharges selon 5.2.4.6.

   iii) Un *BDM/CDM/PDS* dont les moteurs sont équipés d'une protection thermique (c'est-à-dire sur ou dans les moteurs) exigeant des *accès* avec le *BDM/CDM/PDS* doit comporter des moyens de connexion à la protection thermique.

   iv) La régulation de limitation de courant temporisée ne doit pas être considérée comme étant équivalente à la protection contre les surcharges du moteur.

   v) Le circuit d'alimentation de l'inducteur du moteur d'un *BDM/CDM/PDS* en courant continu ne doit pas contenir de protection contre les *surintensités,* sauf si le *BDM/CDM/PDS* comporte un détecteur qui peut

      – empêcher la survitesse sous perte de champ, et

      – détecter la perte de courant ou de tension de champ.

h) Disjoncteurs à *déclenchement* instantané

   i) Un disjoncteur à *déclenchement* instantané doit satisfaire aux exigences de construction applicables de la CSA C22.2 No. 5.

   ii) Les dispositifs réglables d'un disjoncteur à *déclenchement* instantané ou d'un dispositif de commande autoprotégé accessibles sans ouvrir une *porte* ou retirer un *capot* doivent être prévus de manière à pouvoir installer une butée pour limiter le réglage maximal. Les instructions d'installation de la butée doivent être incluses avec le contrôleur complet.

iii) Si un dispositif de protection contre les coupures de phase est fourni, il doit fonctionner en cas de perte de puissance dans l'un des conducteurs d'un circuit polyphasé afin de provoquer et de maintenir l'interruption de puissance dans l'ensemble du circuit. Un dispositif de protection contre les coupures de phase destiné à une machine à fonctionnement intermittent (dont la course et la durée de fonctionnement continu sont définitivement limitées) peut fonctionner uniquement pour empêcher le redémarrage du moteur en cas de perte de puissance dans l'un des conducteurs du moteur. Voir 5.2.4.12 pour l'essai.

   iv) Si un dispositif de protection contre l'inversion de phase est fourni, il doit fonctionner à l'inverse de la rotation de phase dans un circuit polyphasé afin de provoquer et de maintenir l'interruption de puissance dans l'ensemble du circuit.

i) Porte-fusibles

   i) Un porte-fusible doit être de type à cartouche ou de type bouchon. Un porte fusible à cartouche doit accepter un fusible supplémentaire, comme cela est décrit en T.4.13.6.200 8) f) ii) 1), ou un fusible de circuit de dérivation, selon celui dont l'utilisation est prévue.

   ii) La construction du *BDM/CDM/PDS* intégrant un porte-fusible et l'emplacement des fusibles (dont le fonctionnement normal exige un renouvellement) doivent être tels que les fusibles soient aisément accessibles lorsque les contacts du commutateur sont ouverts pour permettre le replacement sans s'exposer à une *partie active*. La disposition électrique d'un interrupteur unipolaire doit être telle que, si elle est correctement connectée, les bornes du fusible sont inactives lorsque les contacts du commutateur sont ouverts.

   NOTE 2 Il n'est pas exigé de remplacer un fusible de *circuit de commande* dans le cadre d'une fonction normale, à condition que le fusible et la charge de *circuit de commande* (autre qu'une charge de *circuit de commande* fixe, telle qu'une lampe témoin, par exemple) se trouvent dans la même enveloppe.

   iii) Les *distances d'isolement* et *lignes de fuite* des fusibles et des porte-fusibles, mesurées lorsque les fusibles sont en place, doivent être déterminées en utilisant des fusibles présentant les dimensions normalisées maximales, les *distances d'isolement* et *lignes de fuite* ne devant pas être inférieures à celles spécifiées en 4.4.7.4 et 4.4.7.5.

Tableau T.22 – Valeurs d'essai de rigidité diélectrique des *BDM/CDM/PDS haute tension*, kV

Tension nominale (kV)	**Essai de rigidité diélectrique** (sous tension élevée)	**Essai aux ondes de choc** (BIL)	**Extinction de l'effet couronne**
1,2	4,7	8	0,9
2,4	7,4	14	1,8
3,6	10,1	20	2,7
4,16	11,36	23,11	3,5
7,2	18,2	40	5,5
12	29	60	9,1
13,8	32,15	64,91	10,5
14,4	33,2	66,55	10,75
18	39,5	76,54	14
27,6	56,3	104	19
34,5	68,38	121,3	26,5

T.4.14 Protection contre les champs électromagnétiques

Le paragraphe 4.14 ne s'applique pas.

T.5 Exigences d'essais

T.5.1 Généralités

T.5.1.1 Objectifs et classification des essais

Modification du 5.1.1:

Les *essais sur prélèvement* ne s'appliquent pas.

T.5.2 Spécifications des essais

T.5.2.1 *Inspections visuelles* (*essai de* type, *essai* individuel *de série* et *essai sur prélèvement)*

T.5.2.2 Essais mécaniques

T.5.2.2.1 *Essais* de *distances d'isolement* et de *lignes* de fuite (essai de *type)*

T.5.2.2.2 Essai de non-accessibilité *(essai de type*)

Ajout d'un paragraphe supplémentaire à 5.2.2.2:

T.5.2.2.2.200 Essai de non-accessibilité (*essai de type*)

Essai d'entrée d'une tige pour un *BDM/CDM/PDS* assigné à au moins 750 V.

Cet essai, s'il est réalisé pour déterminer l'accessibilité des *parties actives*, doit être le suivant.

1) Si les *parties actives* sont à moins de 102 mm d'une ouverture, cet essai doit être réalisé en tenant d'insérer une tige de 12,7 mm de diamètre.
2) Si les *parties actives* sont à au moins 102 mm d'une ouverture, cet essai doit être réalisé en tenant d'insérer une tige de 19 mm de diamètre.
3) Le *BDM/CDM/PDS* doit être considéré comme satisfaisant à cette exigence si la tige ne peut pas entrer dans l'ouverture.

T.5.2.2.3 Essai d'intégrité de l'enveloppe (classification IP) (*essai de type*)

Ajout à 5.2.2.3:

Lorsque cela est exigé par T.4.12.1 1), les *BDM/CDM/PDS* autres que ceux utilisés dans le cadre d'une utilisation générale en intérieur doivent être soumis à l'essai conformément à la CSA C22.2 No.94.2.

T.5.2.2.4 *Essai* d'intégrité de l'enveloppe *(essai de type*)

T.5.2.2.4.1 Généralités

T.5.2.2.4.2 Essai de flexion *(essai de type*)

Ajout à 5.2.2.4.2:

1) Un *porte* étirée, gaufrée, à brides ou renforcée de la même manière, un panneau frontal ou un *capot* constitué de métal d'une épaisseur inférieure à celle spécifiée dans le Tableau T.17 et dans le Tableau T.18 ne doit pas se plier vers l'intérieur de plus de 6,5 mm lorsqu'une force verticale de 445 N est appliquée en tout point de la *porte*, du panneau frontal ou du *capot*.
2) La force doit être appliquée avec une barre présentant une face plate et carrée de 13 mm sur un bord. L'essai doit être réalisé avec la *porte*, le panneau frontal ou le *capot* monté sur le boîtier de la manière prévue, le dos de l'*enveloppe* reposant sur une surface horizontale plate fixe.

T.5.2.2.4.3 Essai de choc *(essai de type*)

Ajout d'un paragraphe supplémentaire à 5.2.2.4:

T.5.2.2.4.200 Essai de résistance aux chocs sur les fenêtres d'observation (*essai de type*)

1) L'essai doit être réalisé sur un seul échantillon à une *température ambiante* comprise entre 10 °C et 40 °C.
2) L'essai doit être réalisé avec un choc, comme suit:
   a) 7,0 J ± 0,2 J pour les matériaux utilisant une protection contre les dangers de chocs électriques, les dangers d'incendie ou les dangers mécaniques; ou
   b) 0,5 J pour les matériaux destinés à des applications autres que celles couvertes en a).
3) Un seul choc doit être appliqué perpendiculairement à la surface, le *BDM/CDM/PDS* étant dans sa position normale.
4) Le choc ne doit pas entraîner les conditions spécifiées en 5.2.2.4.1 a) à f).

5) Le choc doit être appliqué par une sphère en acier solide et lisse de 50 mm ± 1 mm de diamètre et pesant environ 0,53 kg. Pour les surfaces supérieures, la sphère en acier doit pouvoir tomber librement sur la distance exigée de manière à frapper l'*enveloppe* au moment auquel la sphère comporte de l'énergie spécifiée. Pour les autres surfaces, la sphère en acier doit être suspendue par un mince fil et doit être laissée tomber comme un pendule sur la distance exigée de manière à frapper la surface avec la force spécifiée, l'*enveloppe* devant être placée de sorte que la surface à soumettre à l'essai soit verticale et se trouve dans le même plan vertical que le point de support du pendule.

T.5.2.2.5 Essai des BDM/CDM/PDS fixés *au* mur ou au plafond (*essai de type*)

Le paragraphe 5.2.2.5 ne s'applique pas.

T.5.2.2.6 Essai de fixation des poignées et organes *de* contrôle manuels (*essai de type*)

Le paragraphe 5.2.2.6 ne s'applique pas.

T.5.2.2.7 Essai de relâchement des contraintes (essai de type)

T.5.2.2.8 Essai des dispositifs *d'isolation* et de l'intégrité *du* verrouillage (*essai de type*)

T.5.2.2.9 Essai de bruit acoustique *(essai de type*)

Le paragraphe 5.2.2.9 ne s'applique pas.

Ajout de paragraphes supplémentaires à 5.2.2:

T.5.2.2.200 Essais des connexions du conduit et essai de courbure (*essai de type*)

1) Une *enveloppe* polymère destinée à être reliée à un *système* de conduit rigide doit résister, sans écartement ni dommages (fissures et rupture, par exemple) à l'essai de traction, à l'essai serrage et à l'essai de courbure spécifiés en T.5.2.2.200 2), 3), 4) et 5). L'essai de serrage ne doit pas être réalisé sur une *enveloppe* qui n'est pas équipée d'une entrée préassemblée et qui ne fait l'objet d'aucune instruction spécifiant que l'entrée doit être reliée au conduit avant d'être connectée à l'*enveloppe*.
2) L'*enveloppe* doit être suspendue par une longueur de conduit rigide installée sur l'une de ses parois. Une traction directe de 890 N doit être appliquée pendant 5 min jusqu'à une longueur de conduit installée sur la paroi opposée.
3) L'*enveloppe* doit être solidement montée comme prévu en service. Le couple doit être appliqué à une longueur de conduit installé dans un sens qui permet de serrer la connexion. Le bras de levier doit être mesuré depuis le centre du conduit. Le couple de serrage doit être conforme au Tableau T.23, à ceci près qu'il n'est pas nécessaire que l'*enveloppe* de bout de ligne fasse uniquement l'objet d'un couple de serrage de 22 Nm.

   NOTE Une enveloppe de bout de ligne est une enveloppe qui est destinée à être reliée à l'extrémité d'une section de conduit et dont la dimension commerciale maximale de l'ouverture est de 3/4 pour la connexion du conduit.

4) Flexion

a) Une longueur de conduit adaptée d'au moins 300 mm et de dimension appropriée doit être installée

i) au centre de la surface renforcée la plus large, ou

ii) dans une entrée ou une ouverture, si elle fait partie de l'*enveloppe*. L'*enveloppe* doit être solidement montée comme prévu en service, mais positionnée de sorte que le conduit installé s'étende dans un plan horizontal.

La masse nécessaire pour produire le moment de flexion souhaité lors de la suspension à l'extrémité du conduit doit être déterminée par la formule suivante:

$$W = \frac{0{,}102 \times M - 0{,}5 \times C \times L}{L}$$

où

W est la masse à suspendre à l'extrémité du conduit, kg;

M est le moment de flexion exigé, Nm;

C est la masse du conduit, kg;

L est la longueur du conduit entre la paroi de l'*enveloppe* et le point auquel la masse est suspendue, m.

b) Le moment de flexion correspondant à l'essai spécifié en T.5.2.2.200 4) a) doit être comme cela est spécifié dans le Tableau T.24. Si la surface de l'*enveloppe* peut être installée soit dans un plan vertical soit dans un plan horizontal, la valeur du moment de flexion vertical doit être utilisée. Pour une *enveloppe* de bout de ligne (voir T.5.2.2.200 3)), il est seulement nécessaire que le moment de flexion soit de 16,9 Nm.

5) Si des ouvertures défonçables sont intégrées dans la conception d'une *enveloppe* constituée de matériau polymère, elles doivent rester en place lorsqu'une force de 89 N est appliquée perpendiculairement au moyen d'un mandrin à extrémité plate de 6,3 mm de diamètre. Le mandrin doit être appliqué à l'endroit le plus susceptible d'entraîner le mouvement de l'ouverture défonçable.

Tableau T.23 – Couple de serrage pour l'essai des entrées de conduit des *enveloppes* polymères

Dimension commerciale du conduit in	Couple de serrage Nm
3/4 et plus petit	90
1, 1-1/4, 1-1/2	113
2 et plus grand	181

Tableau T.24 – Moment de flexion

Plan de montage normal de la surface de l'*enveloppe*	Dimension du conduit	Moment de flexion du conduit Nm	
		Métallique	Non métallique
Horizontal	Tous	34	34
Vertical	1/2–3/4 1 et au-dessus	34 68	34 34
L'essai peut se terminer avant d'atteindre les valeurs spécifiées si la flexion du conduit dépasse 250 mm pour une longueur de conduit de 3 m.			

T.5.2.2.201 Essai de fixation d'un *capot* à pression (*essai de type*)

Un *capot* à pression, comme cela est admis en T.4.12.200 2), doit résister aux essais suivants.

1) Un *capot* qui peut se désengager de sa fixation en appliquant une force de pression avec une main ne doit pas être retiré lorsqu'une force de pression maximale de 62 N est appliquée en deux points qui ne sont pas séparés de plus de 125 mm. La distance doit être mesurée par une bande étirée sur cette partie de la surface du *capot* englobée par la pomme de la main. L'essai doit être réalisé tel quel et après avoir retiré et remplacé le *capot* 10 fois.
2) Un *capot* ne doit pas se désengager de l'*enveloppe* lorsqu'une traction directe de 62 N est appliquée en saisissant le *capot* en deux endroits prévus à cet effet. L'essai doit être réalisé tel quel et après avoir retiré et remplacé le *capot* 10 fois.
3) Un *capot* ne doit pas se déplacer lorsqu'une force de choc de 1,4 J est appliquée sur ses faces accessibles (un coup par face). Le choc doit être appliqué par une bille d'acier d'au moins 25 mm de diamètre.

T.5.2.2.202 Essai de compression (*essai de type*)

Comme cela est exigé en T.4.12.4, une *enveloppe* construite en métal plus fin que ce qui est spécifié dans le Tableau T.17 et dans le Tableau T.18 doit être renforcée, de sorte que sa flexion ne soit pas supérieure à celle d'une *enveloppe* en tôle de référence de longueur et de largeur maximales construite avec l'épaisseur de tôle exigée minimale.

L'*enveloppe* doit reposer sur une surface horizontale plate fixe. Une force verticale doit être appliquée en tout point des surfaces de l'*enveloppe*, sauf pour la *porte* ou le *capot*, à l'aide d'une barre en acier à face plate de section 13 mm². La force doit être appliquée sur les parois d'extrémité, latérales et arrières de chaque *enveloppe*. La valeur de la force et la limite de flexion, chacune devant être mesurée et consignée, ne sont pas spécifiées, mais la force exercée sur chaque paroi de l'*enveloppe* d'essai et de l'*enveloppe* de référence doit être suffisante pour entraîner une flexion mesurable sur l'*enveloppe* d'essai.

T.5.2.3 Essais électriques

T.5.2.3.1 Généralités

T.5.2.3.2 *Essai de tension* de tenue *aux chocs (essai* de *type, essai sur prélèvement*)

Ajout à 5.2.3.2:

1) Un circuit commandé par chocs doit résister, sans rupture, à une seule impulsion de choc de 1,2 µs x 50 µs avec une valeur de crête de 5 000 V pour les *BDM/CDM/PDS basse tension* et une valeur BIL conforme au Tableau T.22 pour les *BDM/CDM/PDS haute tension* (voir l'ANSI/IEEE 4).
2) Le *BDM/CDM/PDS* doit être relié à une source d'alimentation fonctionnant à la tension assignée, la sortie du générateur d'impulsions étant reliée aux phases d'entrée du *BDM/CDM/PDS*.
3) Pour les *BDM/CDM/PDS* intégrant des parafoudres, l'essai de *tension de tenue aux chocs* peut être réalisé avec les parafoudres en place. Si le parafoudre se déclenche avant que la tension de crête spécifiée en T.5.2.3.2 1) ne soit atteinte, il doit être retiré du circuit et l'essai de *tension de tenue aux chocs* doit être répété à l'aide d'une tension de crête supérieure ou égale à la tension de décharge observée avec le parafoudre en place.
4) Les dispositifs de suppression des transitoires (varistances ou dispositifs de protection contre les tensions de choc transitoires, par exemple) doivent être évalués selon les exigences de *composants* de la CSA C22.2 No. 269.5.

T.5.2.3.3 Alternative à *l'essai de tension* de tenue *aux chocs (essai* de *type, essai sur prélèvement*)

T.5.2.3.4 Essai de tension en courant alternatif *ou en courant continu* (*essai de type* et *individuel de série*)

T.5.2.3.4.1 But de l'essai

T.5.2.3.4.2 Valeur et type de la tension d'essai

Ajout à 5.2.3.4.2:

1) Le *BDM/CDM/PDS* doit résister, pendant 1 min sans rupture, à l'application d'une tension essentiellement sinusoïdale de 50 Hz ou 60 Hz de
   a) 500 V pour les dispositifs assignés à 50 V au maximum,
   b) 1 000 V plus deux fois la tension assignée maximale pour les dispositifs assignés entre 51 V et 750 V,
   c) 2 000 V plus 2,25 fois la tension assignée maximale pour les dispositifs assignés entre 751 V et 1 500 V, et
   d) selon le Tableau T.22 pour les *BDM/CDM/PDS haute tension*.
2) Pour les *essais individuels de série* uniquement, l'essai peut durer 1 s si la tension d'essai est 20 % supérieure à celle spécifiée en T.5.2.3.4.2 1) a), b) ou c).
3) Si la tension d'essai est appliquée pour évaluer la *protection renforcée*, sa valeur doit être conforme à 5.2.3.4.2.
4) Si le *BDM/CDM/PDS* contient un ou plusieurs compteurs, ces instruments peuvent être déconnectés du circuit comme cela est spécifié en T.5.2.3.4.2 1). Les compteurs doivent ensuite être soumis à l'essai séparément pour la rigidité diélectrique avec une tension appliquée de
   a) 1 000V en courant alternatif plus deux fois la tension assignée maximale entre le circuit d'alimentation *basse tension* et des parties métalliques non porteuses de courant exposées,
   b) 1 000 V en courant alternatif plus deux fois la tension assignée maximale entre les *parties actives* du circuit *basse tension* et les *parties actives* des circuits fonctionnant à 50 V au maximum,
   c) 500 V en courant alternatif entre les parties métalliques non porteuses de courant exposées et les circuits (y compris les compteurs) fonctionnant à 50 V au maximum (aucune exigence d'essai n'est spécifiée pour les circuits fonctionnant à 30 V au maximum), et
   d) 2 000 V en courant alternatif plus 2,25 fois la tension assignée maximale pour les dispositifs assignés au-dessus de 750 V, appliquée entre les circuits d'alimentation et des parties métalliques non porteuses de courant.
5) Si le *BDM/CDM/PDS* contient des assemblages de circuit imprimé et d'autres *composants* de circuit électronique compromis par l'application de la tension d'essai (ou qui sont conçus pour protéger le *BDM/CDM/PDS* de la tension), ils doivent être retirés ou rendus inopérants avant de procéder aux essais diélectriques. Un sous-ensemble représentatif peut être soumis à l'essai à la place d'une unité complète. L'*isolation* et les *distances d'isolement* et *lignes de fuite* des circuits utilisant ces dispositifs doivent ensuite être soumises à l'essai de rigidité diélectrique séparément, avec une tension appliquée de
   a) 1 000 V en courant alternatif plus deux fois la tension assignée maximale entre le circuit d'alimentation *basse tension* et des parties métalliques non porteuses de courant exposées,
   b) 1 000 V en courant alternatif plus deux fois la tension assignée maximale entre les *parties actives* du circuit *basse tension* et les *parties actives* des circuits fonctionnant à 50 V au maximum, et

c) 500 V en courant alternatif entre les parties métalliques non porteuses de courant exposées et les circuits (y compris les compteurs) fonctionnant à 50 V au maximum (aucune exigence d'essai n'est spécifiée pour les circuits fonctionnant à 30 V au maximum).

6) Pour déterminer si le *BDM/CDM/PDS* satisfait aux exigences du T.5.2.3.4.2 1) 2), le dispositif doit être soumis à l'essai à l'aide d'un transformateur adapté de 500 VA ou d'une capacité plus importante, dont la tension de sortie est essentiellement sinusoïdale et peut varier. La tension appliquée doit être augmentée de zéro à la valeur exigée à une vitesse plutôt uniforme et aussi rapidement que sa valeur indiquée par un voltmètre le permet. La tension doit être maintenue à cette valeur pendant 1 min.

7) S'il s'avère plus pratique de procéder ainsi, l'essai de rigidité diélectrique peut être réalisé en appliquant une tension en courant continu en lieu et place d'une tension en courant alternatif, à condition que la tension utilisée soit égale à 1,4 fois les valeurs spécifiées en T.5.2.3.4.2 1).

T.5.2.3.4.3 Considérations d'essai supplémentaires

T.5.2.3.4.4 Exécution de l’essai de tension

Ajout à 5.2.3.4.4:

Un transformateur, une bobine, un dispositif électronique non utilisé comme dispositif d'isolation ou un dispositif analogue normalement relié entre les phases de polarité opposée, doit être déconnecté d'un côté de la phase pendant l'essai. Pour créer un circuit continu pour la tension d’essai sur le *BDM/CDM/PDS*, les bornes, les contacts ouverts de commutateurs ainsi que les semiconducteurs de puissance, etc. doivent être pontés si nécessaire.

Avant de procéder à l’essai, les semiconducteurs et autres *composants* vulnérables à l’intérieur d’un circuit peuvent être déconnectés et/ou leurs bornes peuvent être pontées pour éviter de les endommager pendant l’essai.

T.5.2.3.4.5 Durée de l’essai de tension en courant alternatif ou en courant continu

Modification du 5.2.3.4.5:

Les durées spécifiées ne s’appliquent pas et sont remplacées par T.5.2.3.4.2 1) et 2).

T.5.2.3.5 Essai de décharge partielle *(essai* de *type, essai sur prélèvement*)

Remplacement du 5.2.3.5:

1) L'essai de l'effet de couronne est facultatif pour les *BDM/CDM/PDS* assignés à 15 000 V au maximum. L'essai d'un *BDM/CDM/PDS haute tension* peut être réalisé sur des sous-ensembles, s'il s'avère impossible de procéder à l'essai sur le *BDM/CDM/PDS* complet.

2) Si des essais d'extinction de l'effet couronne sont exigés, l'amplitude admise maximale de l'alternance d'effet de couronne doit être de 100 pC lorsque les *BDM/CDM/PDS* sont soumis à l'essai avec la tension d'extinction de l'effet couronne spécifiée dans le Tableau T.22.

NOTE Voir T.5.2.3.200 pour des recommandations relatives au mesurage de l'effet de couronne dans les *BDM/CDM/PDS haute tension*.

Ajout d’un paragraphe supplémentaire à 5.2.3:

T.5.2.3.200 Lignes directrices pour le mesurage de l'effet de couronne dans les *BDM/CDM/PDS* (informative)

T.5.2.3.200.1 Généralités

Le paragraphe T.5.2.3.200 consolide les informations actuelles sur l'art de détecter une décharge en couronne dans les *composants BDM/CDM/PDS* et les ensembles.

Les tensions de seuil et d'extinction de l'effet de couronne sont importantes dans la conception des *systèmes* d'*isolation*. La présence d'un effet de couronne à la tension de fonctionnement peut entraîner une réduction importante de la durée de vie de certains matériaux d'*isolation*. Certains sont plus susceptibles d'être endommagés que d'autres. Les paramètres d'effet de couronne, en particulier l'amplitude d'alternance d'effet de couronne et la vitesse de répétition, ont un impact sur la vitesse de détérioration. Toutefois, l'effet de couronne détecté commence parfois en des endroits (des fils ou des bornes, par exemple) où il n'a pas d'impact significatif sur l'*isolation* dans l'éprouvette. En règle générale, l'effet de couronne n'est pas une caractéristique du matériau, mais une fonction d'un *système* d'*isolation* incluant les électrodes.

L'effet de couronne est influencé par les conditions environnementales (la température, la pression atmosphérique, l'humidité, l'immersion dans un liquide, par exemple) et la précédente électrification. La tension d'extinction de l'effet couronne est souvent nettement inférieure à la tension de seuil. Si la tension de fonctionnement est inférieure à la tension de seuil de l'effet couronne, mais qu'elle est supérieure à la tension d'extinction, une surtension peut déclencher un effet de couronne, qui peut alors durer tant que la tension n'est pas retombée sous le niveau d'extinction.

T.5.2.3.200.2 Domaine d’application du mesurage de l'effet de couronne dans les *BDM/CDM/PDS*

1) Le paragraphe T.5.2.3.200 couvre le mesurage, aux fréquences industrielles, de la tension de seuil de l'effet couronne et de la tension d'extinction de l'effet couronne aux bornes des *composants* du *BDM/CDM* et des ensembles.
2) Les niveaux de tension d'extinction de l'effet couronne, les grandeurs de décharge et les points d'application de la tension d'essai sont spécifiés en T.5.2.3.5 et dans le Tableau T.22.
3) Le paragraphe T.5.2.3.200 porte sur la détermination pratique des niveaux de l'effet de couronne et pas sur ses effets sur les différents matériaux d'*isolation*. Par conséquent, aucune référence aux niveaux d'énergie, aux courants de décharge, etc., n'a été formulée.

T.5.2.3.200.3 Définitions relatives au mesurage de l'effet de couronne

Outre les définitions de l’Article 3 et du paragraphe T.3, les définitions suivantes doivent s'appliquer dans le paragraphe T.5.2.3.200:

Effet de couronne – décharge à l'intérieur du système d'isolation qui n'entraîne pas la défaillance complète.

Échantillon sans effet de couronne – échantillon dont la tension d'extinction de l'effet couronne est 25 % supérieure au niveau CEV spécifié pour cette classe de tension.

Tension d'extinction de l'effet couronne (CEV – *corona extinction voltage*) – tension en valeur efficace appliquée à laquelle l'effet de couronne au-dessus de la grandeur spécifiée n'est plus observé au fur et à mesure de la diminution de tension de plus de la tension de seuil de l'effet couronne.

Tension de seuil de l'effet couronne (CIV – *corona inception voltage*) – tension en valeur efficace la plus basse appliquée à laquelle l'effet de couronne au-dessus de la grandeur spécifiée est observé au fur et à mesure de l'augmentation de tension.

Grandeur de décharge (d'une décharge partielle, souvent appelée charge apparente "q") – charge qui, si elle est injectée instantanément entre les bornes de l'objet en essai, fait momentanément varier la tension entre les bornes dans les mêmes proportions que la décharge partielle elle-même.

NOTE La *charge apparente "q"* ainsi définie n'est pas égale à la quantité de charge réellement transférée par la cavité de décharge dans l'essai diélectrique. Elle est utilisée car les instruments de mesure de décharge répondent à cette grandeur.

T.5.2.3.200.4 Conditions d'essai de l'effet de couronne

1) La fréquence de la tension d'alimentation doit être de 60 Hz ± 5 %. Une onde sinusoïdale d'une norme commerciale acceptable est préférentielle. La tension doit être relevée à l'aide d'un instrument de relevé de crête et les relevés être exprimés en valeurs efficaces équivalentes ou les tensions de crête être divisées par la racine carrée de deux.
2) Les essais doivent être réalisés uniquement lorsque l'équipement et l'environnement d'essai sont tels qu'il n'y a pas de signes visibles de l'effet de couronne lorsque l'échantillon d'essai est remplacé par un échantillon sans effet de couronne (avec une capacité du même ordre de grandeur que l'échantillon d'essai) et qu'une tension d'essai appliquée est 25 % supérieure à la tension d'extinction de l'effet couronne.
3) Les effets des conditions atmosphériques étant inconnus, une température, une humidité ou une pression anormale ne doit faire l'objet d'aucune correction, mais il est recommandé
   a) de procéder aux essais lorsque la pression de vapeur de l'humidité dans l'air est comprise entre 0,2 pouce de mercure et 0,6 pouce de mercure,
   b) de consigner la pression barométrique et les relevés du psychromètre d'Assmann, et
   c) de procéder aux essais lorsque la *température ambiante* est comprise entre 15 °C et 30 °C.
4) Les connexions et fils provisoires doivent être blindés de manière à empêcher la formation de l'effet de couronne sur eux, ce qui masque ou empêche de déterminer l'effet de couronne pendant les essais.

T.5.2.3.200.5 Équipement d'essai de l'effet de couronne

1) Le circuit d'essai principal doit être comme cela est présenté à la Figure T.3. D'autre part, se cela est approprié, les circuits d'essai présentés à la Figure T.4, à la Figure T.5 et à la Figure T.6 peuvent être utilisés.
2) La source de puissance doit satisfaire aux conditions du T.5.2.3.200.4, 1) et 2). La capacité de la source doit être suffisante pour alimenter la charge kVA exigée pour la charge de l'échantillon et le condensateur de couplage. L'ajout de filtres aux bornes d'entrée et de sortie de la source peut s'avérer nécessaire pour réduire les influences extérieures et réduire le plus possible la perte du signal d'effet de couronne.

   NOTE 1 kVA exigés = 0,377 x C x E^2 où C est exprimé en microfarads et E est exprimé en kilovolts.
3) Il convient que la valeur du condensateur de contournement ou du condensateur de couplage, C_{cc}, soit supérieure ou égale à la capacité de l'éprouvette d'essai, C_t, et satisfasse aux conditions du T.5.2.3.200.4 2).
4) Étalonnage de l'équipement d'essai
   a) Un générateur d'impulsions doit être connecté aux bornes de l'éprouvette afin de fournir une alternance de l'amplitude adaptée atteignant la valeur de crête en 0,1 μs au maximum et ne diminue pas à moins de la moitié de la valeur de crête en 1 ms.

      NOTE 2 Un générateur d'ondes carrées satisfaisant à ces exigences est une bonne source d'alternances.
   b) Le circuit doit être étalonné par un instrument lui-même étalonné qui peut être un oscilloscope, un générateur d'ondes carrées ou un autre équipement approprié.
   c) Voir la Figure T.7 pour les courbes représentant la sensibilité classique d'un ensemble d'essais.
   d) Voir le Tableau T.25 pour les équations de sensibilité du circuit d'essai.

T.5.2.3.200.6 Essai de l'effet de couronne

1) Condition
   a) L'échantillon d'essai doit rester dans l'environnement d'essai suffisamment longtemps pour stabiliser sa température et son humidité.
   b) L'échantillon d'essai doit être propre et sec.
2) Connexions
   a) L'échantillon d'essai doit être connecté au circuit dans les conditions similaires à celles de son environnement de service installé normal en ce qui concerne sa disposition de montage, son plan de masse et ses connexions haute tension.
   b) Si un câblage secondaire est exigé, les fils doivent sortir radialement du corps de l'échantillon vers un plan de masse à une distance adaptée.
   c) Pour les transformateurs de tension ou les transformateurs d'alimentation de commande de type entre phases, l'effet de couronne doit être mesuré pour chacune des connexions suivantes:
      i) tension d'essai appliquée à H1 et H2 liés, X1, X2 et la base étant reliés à la terre.
      ii) tension d'essai appliquée à H1, avec H2, X2 et la base reliés à la terre.
      iii) tension d'essai appliquée à H2, avec H1, X2 et la base reliés à la terre.

      NOTE L'essai spécifié au point i) contraint l'*isolation* principale et l'*isolation* des enroulements primaires et des bornes à la terre. Les essais spécifiés au point ii) et au point iii) contraignent l'*isolation* de spire et de couche des enroulements primaires et des bornes primaires la terre.
   d) Pour les transformateurs de tension ou les transformateurs d'alimentation de commande de type phase/terre, l'effet de couronne doit être mesuré en appliquant la tension d'essai à H1 avec X2, H2 et la base reliés à la terre.

      NOTE 1 Cet essai contraint l'*isolation* de spire et de couche dans l'enroulement primaire et la borne H1 à la terre.

      NOTE 2 Dans l'essai de l'effet de couronne d'un transformateur de tension, il convient que la tension maximale à appliquer ne soit pas supérieure à 140 % de sa tension nominale exacte primaire.
e) Le circuit d'essai des transformateurs de mesure doit être celui présenté à la Figure T.3 ou à la Figure T.4.
3) Procédure d'essai
   a) La tension doit être appliquée et élevée à au moins la moitié de la tension d'essai diélectrique à fréquence industrielle tant que l'effet de couronne ne s'est pas déclenché ou pendant 1 min, puis doit ensuite être réduite à la tension d'extinction de l'effet couronne spécifiée et maintenue à cette tension pendant 2 min au maximum. L'équipement doit être considéré comme ayant satisfait à l'essai si l'effet de couronne observable au-dessus de la grandeur spécifiée a cessé dans les limites de la période de 2 min.
   b) Si, à l'issue de la période de 2 min, l'indication de décharge est évidente uniquement sous la forme d'impulsions brèves parasites ou aléatoires espacées d'au moins 2 s, alors, pour les besoins du T.5.2.3.200, l'effet de couronne au-dessus de la grandeur spécifiée doit être considéré comme ayant cessé.

T.5.2.3.200.7 Sensibilité de l'essai de l'effet de couronne

1) Sensibilité de l'ensemble d'essai

   Les instruments répondent à des variations de tension résultant de décharges en couronne à l'intérieur de l'éprouvette d'essai.

   Pour une grandeur de décharge en couronne donnée, la variation de tension est en principe inversement proportionnelle à la capacité du circuit. Par conséquent, si la capacité de l'éprouvette d'essai augmente, il est exigé d'augmenter le gain ou la sensibilité dans les instruments afin de détecter la même grandeur de décharge en couronne apparente.

2) Circuits d'essai

a) Les circuits présentés à la Figure T.3 et à la Figure T.4 sont recommandés s'il s'avère pratique de comporter une électrode de l'échantillon d'essai reliée à la terre.

b) Les circuits présentés à la Figure T.5 et à la Figure T.6 sont adaptés aux échantillons d'essai de petites dimensions qui peuvent être aisément isolés de la terre.

3) Formules de sensibilité du circuit d'essai

Les formules présentées dans le Tableau T.25 partent du principe que la vitesse de montée des tensions d'effet de couronne et d'alternance étalon est suffisante, que leur répartition initiale dans le circuit est uniquement contrôlée par les capacités du circuit. La capacité répartie dans l'élément de circuit et ses fils de raccordement sont en général considérés comme faisant partie de l'impédance de cet élément. La capacité répartie entre le fil haute tension et la terre a été considérée comme étant négligeable dans ces expressions. Toutefois, il est suggéré que si une exactitude de mesure maximale est souhaitée, la capacité répartie est prise en considération selon l'ASTM D1868.

Tableau T.25 – Formules de sensibilité du circuit d'essai

$\frac{E_c}{H_c} \times C_c \frac{C_{cc} + C_t}{C_{cc}}$	**Formule T.1**
$\frac{E_c}{H_c} \times C_c$	**Formule T.2**
$\frac{E_c}{H_c} \times C_c \frac{(C_{cc} + C_t)}{C_{cc}}$	**Formule T.3**
$\frac{E_c}{H_c} \times C_t$	**Formule T.4**
où E_c est la tension de crête de l'alternance étalon, V; H_c est la flexion maximale par rapport à la trace normale générée par l'alternance étalon, cm; C_t est la capacité de l'éprouvette, pF; C_c est la capacité du condensateur de couplage, pF; C_c est la capacité du condensateur d'étalonnage, pF.	

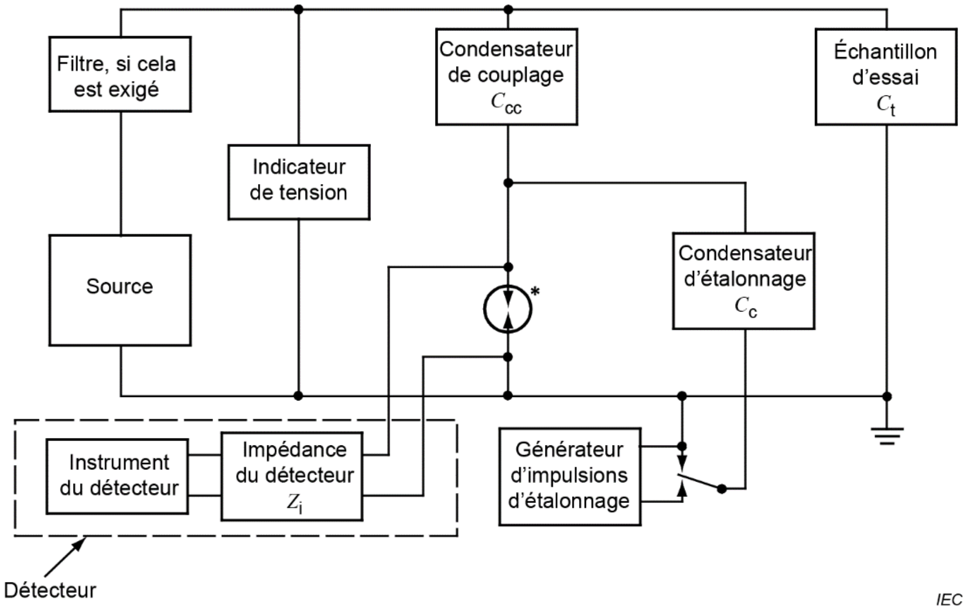


Figure T.3 – Circuit d'essai en utilisant la Formule T.1

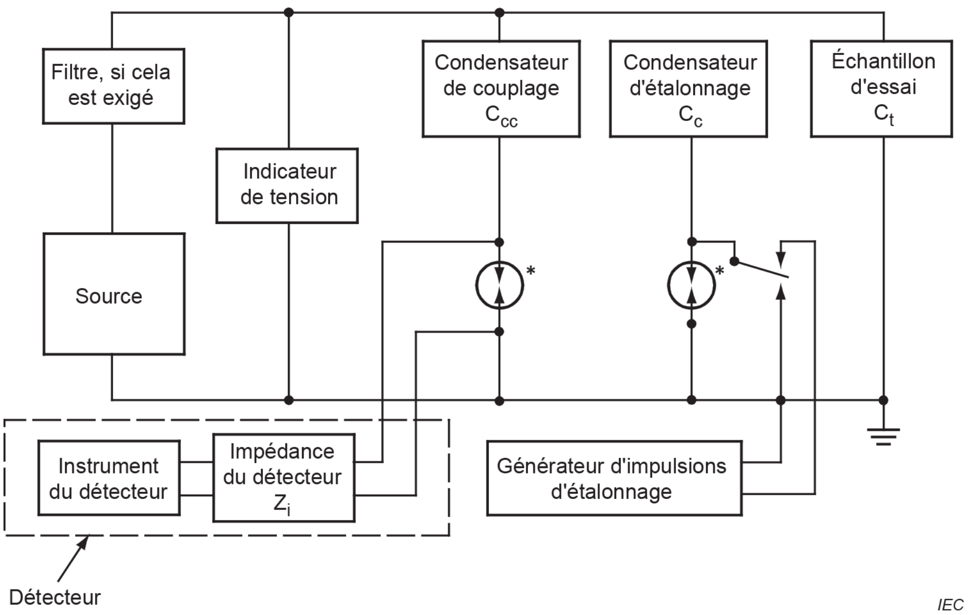


Figure T.4 – Circuit d'essai en utilisant la Formule T.2

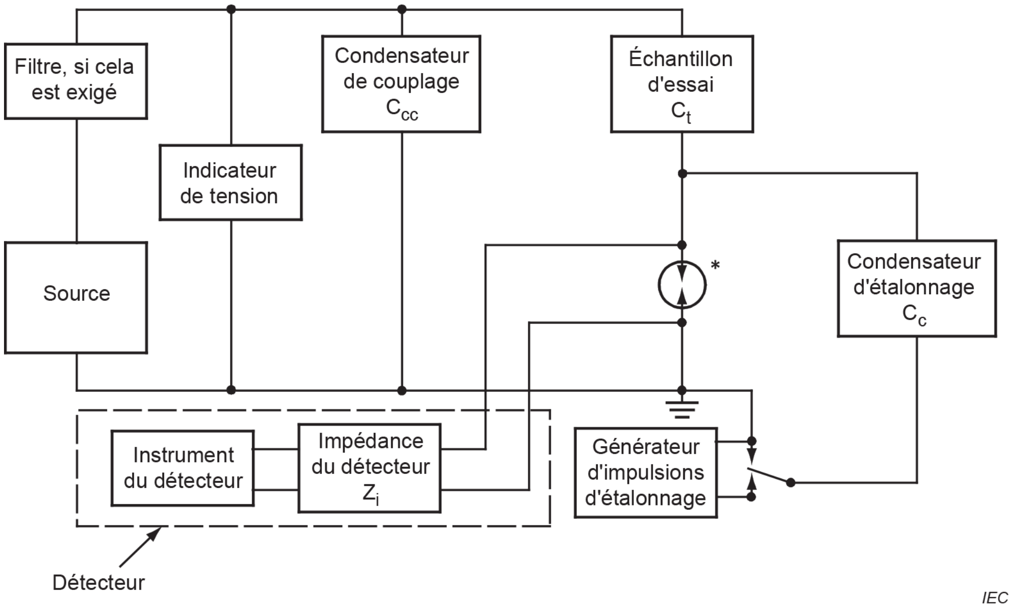


Figure T.5 – Circuit d'essai en utilisant la Formule T.3

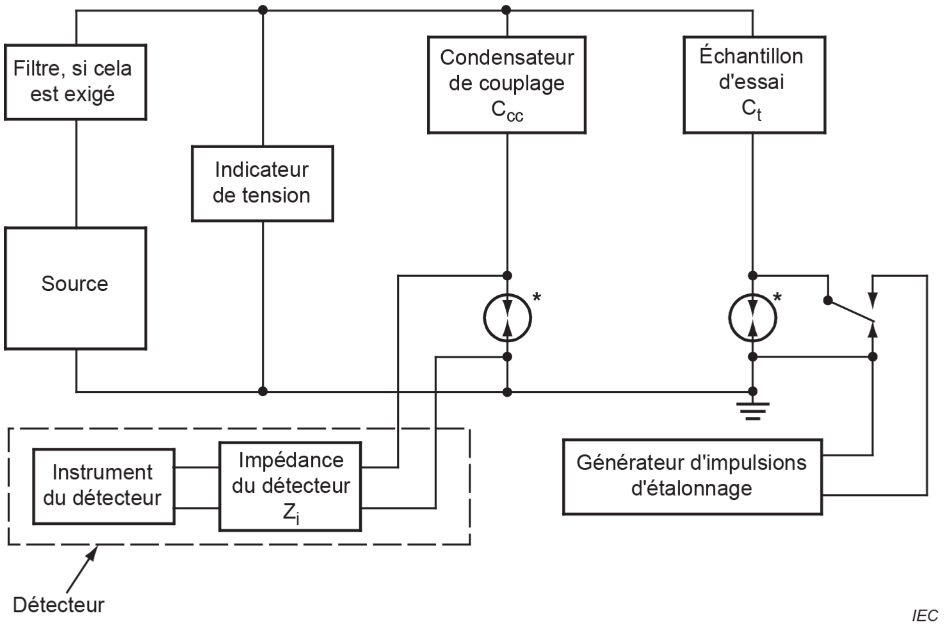


Figure T.6 – Circuit d'essai en utilisant la Formule T.4

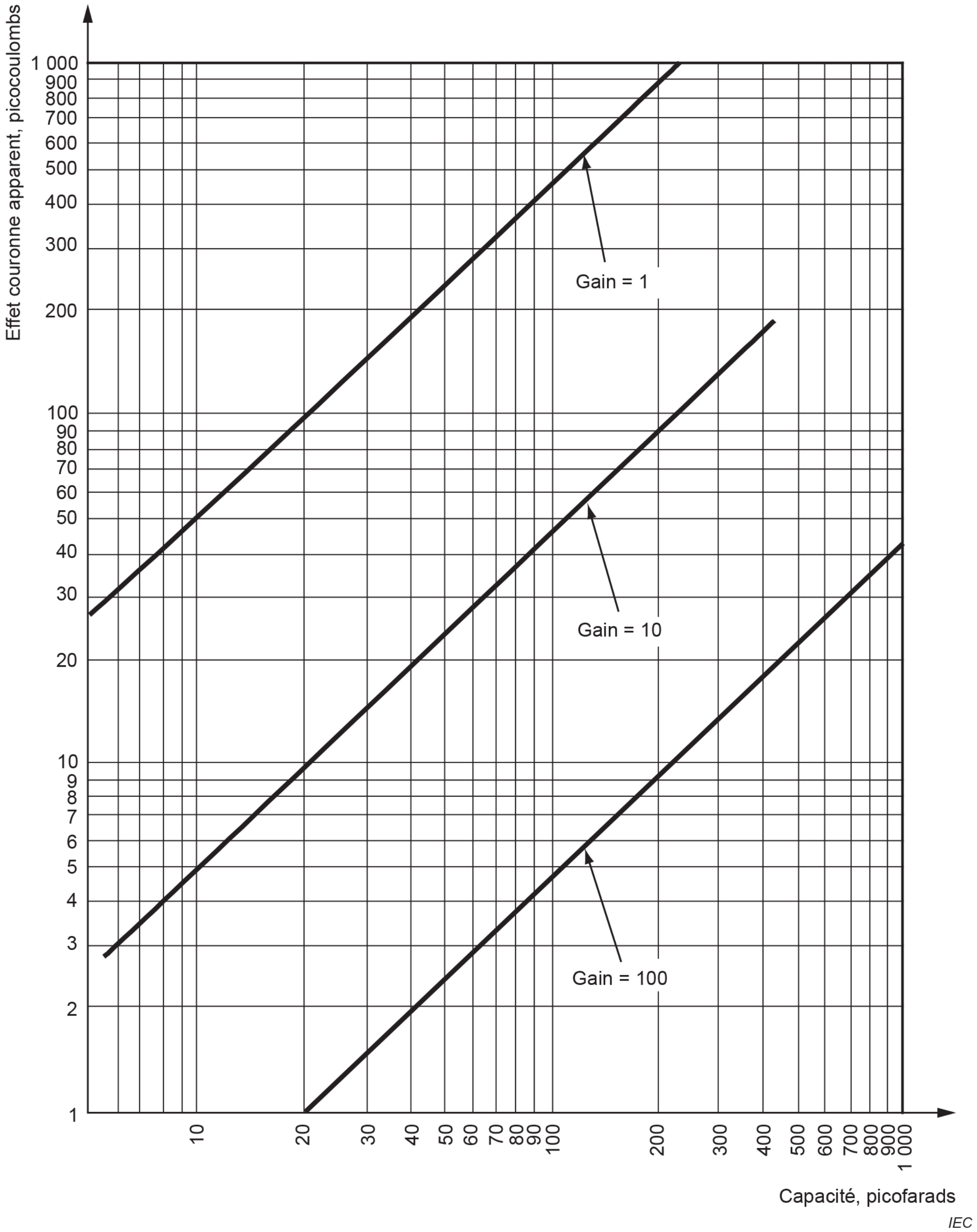


Figure T.7 – Sensibilité de l'ensemble d'essais classique

T.5.2.3.6 *Essai d'impédance* de protection *(essai* de *type, essai individuel de série*)

T.5.2.3.7 *Essai de* mesure du courant *de* contact (*essai de type*)

T.5.2.3.8 Essai de décharge du *condensateur* (*essai de type*)

Modification du 5.2.3.8:

L’option "par calcul" ne s’applique pas; cela doit être réalisé par des essais uniquement.

T.5.2.3.9 Essai de source de puissance *limitée* (*essai de type*)

T.5.2.3.10 Essai d'échauffement (essai *de type*)

Ajout à 5.2.3.10:

1) Les *BDM/CDM/PDS* doivent véhiculer leur courant assigné jusqu'à ce que les températures soient constantes comme suit:
   a) pour un fonctionnement continu, selon les caractéristiques assignées continues;
   b) pour un fonctionnement intermittent, selon le cycle de service assigné.
2) Pour les *BDM/CDM/PDS basse tension*, les essais doivent être réalisés à
   a) la fréquence assignée,
   b) la tension (de réseau) nominale de 120 V, 208 V, 240 V, 277 V, 480 V ou 600 V, selon le cas pour les caractéristiques assignées de tension, et
   c) une tension de 90 % à 110 % de la tension assignée en cas de réglage du courant de charge pour produire le chauffage normal maximal.
3) Pour les *BDM/CDM/PDS haute tension*, l'essai de température peut être réalisé à la tension assignée selon le Tableau T.22 ou à une tension adaptée en cas de réglage du courant de charge pour produire la chaleur normale maximale.
4) Un *BDM/CDM* de *type ouvert* doit être placé dans une *enveloppe* similaire à celle prévue pour l'utilisation. Les dimensions maximales de l'*enveloppe* doivent être établies par l'un des moyens suivants:
   a) une *enveloppe* mesurant 150 % des mesurages du dispositif;
   b) une *enveloppe* satisfaisant à l'espace de courbure des fils du T.4.11.11.4.200;
   c) une boîte de sortie normalisée; ou
   d) une *enveloppe* prévue, dont les dimensions sont supérieures à celles indiquées en T.5.2.3.10 4) a), b) et c) si elles sont indiquées dans les instructions d'installation du fabricant.
5) Le câblage utilisé pour les essais doit satisfaire aux conditions suivantes.

   Un dispositif *BDM/CDM/PDS* doit être soumis à l'essai au courant assigné avec un fil en cuivre de 1 220 mm fixé à chaque *borne pour câblage externe*.
   a) Le fil doit présenter la dimension la plus petite et un courant permanent admissible d'au moins 125 % du courant d'essai pour les charges de moteur et d'au moins 100 % pour les autres charges.
   b) La dimension de fil doit être déterminée selon le Tableau T.26 en fonction de la température nominale du fil marquée sur le *BDM/CDM/PDS*.
   c) Le type d'*isolation* n'est pas spécifié, mais la couleur doit être noire. L'essai de température peut être réalisé avec une *isolation* des conducteurs qui n'est pas noire, mais la température de référence doit être mesurée avec des conducteurs isolés noirs.

   Si la borne ne reçoit pas la dimension de fil exigée pour les essais au courant assigné, la dimension de fil admise maximale doit être utilisée.

6) Si seules des dispositions sont formulées pour la connexion des bus de raccordement assignés à au moins 450 A, des bus de raccordement en cuivre de 6,4 mm d'épaisseur, de la largeur spécifiée dans le Tableau T.27 et d'au moins 1 220 mm de longueur doivent être utilisés. Les bus de raccordement peuvent être peints en noir. La *distance d'isolement* et la *ligne de fuite* entre plusieurs bus de raccordement doivent être de 6,4 mm sans *distance d'isolement* et *ligne de fuite* plus importantes volontaires, sauf si cela est nécessaire au niveau des bornes individuelles du *BDM/CDM/PDS*.

7) Si des mesurages de référence des *températures ambiantes* sont nécessaires, plusieurs thermomètres ou thermocouples doivent être placés en différents endroits autour du *BDM/CDM/PDS* à une distance comprise entre 900 mm et 1 800 mm. Les thermomètres ou thermocouples doivent être placés sur le trajet du liquide de refroidissement, mais être protégés contre les courants d'air et les rayonnements de chaleur anormaux. La *température ambiante* doit être la moyenne des températures mesurées à intervalles réguliers pendant le dernier quart de la durée de l'essai.

8) La pertinence des matériaux d'*isolation*, autres que ceux figurant dans le Tableau 17, doit être déterminée (en fonction de propriétés telles que l'inflammabilité, la résistance à l'arc, etc. (voir le Tableau 17) en s'appuyant sur une température de fonctionnement de 40 °C plus l'échauffement mesuré.

9) Les températures doivent être mesurées à l'aide d'un instrument de type potentiomètre et de thermocouples No. 30 AWG au maximum, après examen, à No. 24 AWG au maximum.

10) La méthode préférentielle de mesure de la température d'une bobine doit être la méthode de la résistance, mais les mesurages de température par la méthode du thermocouple ou de la résistance peuvent être réalisés. La méthode du thermocouple ne doit pas être utilisée pour un mesurage de la température en tout point auquel une *isolation supplémentaire* est utilisée.

11) Comme il est souvent nécessaire de mettre l'enroulement hors tension avant de mesurer la résistance, la valeur de la résistance au moment de l'arrêt peut être déterminée en mesurant plusieurs fois la résistance à de brefs intervalles, en commençant dès que possible après le déclenchement de l'arrêt. Une courbe des valeurs de résistance et de la durée doit être tracée et extrapolée pour donner la valeur de la résistance au moment de l'arrêt.

12) À l'issue de l'essai de température, l'échantillon doit satisfaire aux exigences de l'essai de rigidité diélectrique (essai d'*isolation* en courant alternatif ou en courant continu) du 5.2.3.4.

Tableau T.26 – Courants d'alimentation assignés des conducteurs isolés

Dimension de fil		**60 °C**		**75 °C**	
AWG	mm^2	Cuivre	Aluminium	Cuivre	Aluminium
14	2,1	15	—	15	—
12	3,3	20	15	20	15
10	5,3	30	25	30	25
8	8,4	40	30	50	40
6	13,3	55	40	65	50
4	21,2	70	55	85	65
3	26,7	85	65	100	75
2	33,6	95	75	115	90
1	42,4	110	85	130	100
0	53,5	—	—	150	120
00	67,4	—	—	175	135
000	85,0	—	—	200	155
0000	107,2	—	—	230	180
kcmil					
250	127	—	—	255	205
300	152	—	—	285	230
350	177	—	—	310	250
400	203	—	—	335	270
500	253	—	—	380	310
600	304	—	—	420	340
700	355	—	—	460	375
750	380	—	—	475	385
800	405	—	—	490	395
900	456	—	—	520	425
1 000	506	—	—	545	445
1 250	633	—	—	590	485
1 500	760	—	—	625	520
1 750	887	—	—	650	545
2 000	1 013	—	—	665	560

Pour plusieurs conducteurs de même dimension (1/0 AWG au moins) au niveau d'une borne, le courant permanent admissible est égal à la valeur de ce Tableau de ce conducteur multipliée par le nombre de conducteurs que la borne reçoit.

Ces valeurs de courant permanent admissible s'appliquent uniquement si pas plus de trois conducteurs sont installés sur site dans le conduit. Si au moins quatre conducteurs, autres qu'un conducteur de neutre transportant le courant différentiel, sont installés dans un conduit, les facteurs d'allègement du Tableau T.9 doivent être appliqués.

Tableau T.27 – Dimension des connexions du bus de raccordement en cuivre pour l'essai de température

Caractéristiques assignées du produit A	**Bus de raccordement par borne**	**Largeur du bus de raccordement** mm
450 à 600	1	51
601 à 1000	1	76
1 001 à 1 200	1	102
1 201 à 1 600	2	76
1 601 à 2 000	2	102
2 001 à 2 500	2	127
2 001 à 2 500	4	64
2 501 à 3 000	3	127
2 501 à 3 000	4	102
Voir T.5.2.3.10 6).		

T.5.2.3.11 *Essai de la* liaison équipotentielle *de* protection *(essai* de *type*, *essai individuel de série*)

Modification du 5.2.3.11:

Les essais ne s'appliquent pas et sont remplacés par les essais spécifiés dans la CSA C22.2 No. 0.4.

T.5.2.4 *Essais de* fonctionnement anormal et de défauts simulés

T.5.2.4.1 Généralités

Modification du 5.2.4.1:

Le paragraphe 5.2.4.1 a), b) et c) ne s'applique pas.

Ajout d'un paragraphe supplémentaire à 5.2.4.1:

T.5.2.4.1.200 Essais de *fonctionnement anormal* et de défauts simulés

1) Pour l'essai de court-circuit, un fusible non temporisé de 30 A doit être connecté entre l'*enveloppe* et la terre.
2) Un *BDM/CDM* de *type ouvert* peut également être soumis à l'essai dans une *enveloppe* extérieure satisfaisant aux exigences de dimension et de ventilation spécifiées dans les instructions d'installation du *BDM/CDM/PDS*.
3) Pour les essais de courants de défaut plus élevés, les deux alternatives sont les suivantes:
   a) pour des raisons de sécurité, un générateur de courant électrique constant peut être utilisé à la place d'un fusible de 30 amp; ou
   b) en alternative au fusible de 30 amp à la terre, le montage d'essai peut utiliser un fil relié entre l'*enveloppe* et la terre. La section du fil doit être conforme au Tableau T.2, ou satisfaire aux exigences de dimension de câblage en entrée du T.5.2.4.1.200 5), si cette dernière dimension est plus petite.
4) Les exigences de protection du circuit de dérivation contre les courts-circuits pour la réalisation de l'essai de court-circuit de courant de défaut élevé d'un *BDM/CDM/PDS basse tension* doivent être les suivantes:

a) À l'exception de ce qui est admis en T.5.2.4.1.200 4) b), les fusibles spécifiés pour la protection du circuit de dérivation d'un *BDM/CDM/PDS* assigné à plus de 10 000 A doivent se limiter aux fusibles à haut pouvoir de coupure, de type limiteur de courant (HRCI-R, -J, -T et –MISC ou HRCII-C et –MISC, par exemple).

b) Pour les *BDM/CDM/PDS* assignés à 50 hp au maximum et soumis à l'essai à 10 000 A, des fusibles à cartouche conforme à la série de normes CAN/CSA-C22.2 No. 248 peuvent être spécifiés pour la protection du circuit de dérivation du moteur.

c) Un limiteur d'essai conforme à la CAN/CSA-C22.2 No. 248.16 pour la classe de fusible spécifique peut être utilisé en lieu et place des fusibles spécifiés en T.5.2.4.1.200 4) a) et b).

5) Câblage d'entrée/de sortie

La dimension de fil du câblage d'entrée et de sortie doit être conforme au Tableau T.26. Le courant permanent admissible du câblage doit dépendre de la température nominale du fil indiquée sur le marquage (60 °C ou 75 °C) et de chacun des éléments suivants.

a) Le câblage de puissance d'entrée principal doit être calibré pour 125 % du courant d'entrée du *BDM/CDM/PDS* assigné.

b) Pour les moteurs *basse tension*, le câblage de puissance de sortie du *BDM/CDM/PDS* doit être calibré pour 125 % du courant à pleine charge assigné ou pour 125 % du courant de sortie du moteur à pleine charge indiqué dans le Tableau T.12, en fonction de la caractéristique assignée de cheval-vapeur.

c) Pour les moteurs haute tension, le câblage de puissance de sortie du *BDM/CDM/PDS* doit être calibré pour 125 % du courant à pleine charge assigné, comme cela est spécifié par le fabricant du moteur.

6) Le câblage d'entrée et de sortie peut être acheminé par un conduit de longueur comprise entre 250 mm et 305 mm installé sur l'*enveloppe*. Si aucun conduit n'est utilisé, le fil doit être acheminé par une traversée appropriée à la dimension des conducteurs.

Tableau T.28 – Valeurs d'essai de court-circuit

Caractéristique assignée du dispositif (600 V max.), hp	**Courant à pleine charge**, A, entre 601 V et 1500 V	**Courant d'essai**, A[a]	**Facteur de puissance**[b]
0 à 1-1/2[c]	—	1 000	0,70 à 0,80
0 à 50	0 à 50	5 000	0,70 à 0,80
51 à 200	51 à 200	10 000	0,70 à 0,80
201 à 400	201 à 400	18 000	0,25 à 0,30
401 à 600	401 à 600	30 000	0,20 ou moins
601 à 900	601 à 850	42 000	0,20 ou moins
901 à 1 600	851 à 1 500	85 000	0,20 ou moins

[a] Ampères symétriques en valeur efficace.

[b] Pour les circuits en courant continu, la constante de temps L/R doit être de 3 µs pour les courants d'essai inférieurs ou égaux à 10 000 A au maximum et de 8 µs pour les courants d'essai supérieurs à 10 000 A.

[c] 300 V au maximum, monophasé.

Pour les contrôleurs à courant assigné, utiliser la caractéristique assignée de cheval-vapeur équivalente déduite du Tableau T.12 ou du Tableau T.13, selon le cas.

Pour les *BDM/CDM/PDS* assignés à plus de 750 V, la valeur assignée de court-circuit doit être déterminée par le fabricant, mais elle ne doit pas être inférieure à 10 000 amps.

T.5.2.4.2 Tension, courant et fréquence d'alimentation

Remplacement du Tableau 36 par le Tableau T.28.

Ajout d'un paragraphe supplémentaire à 5.2.4.2:

T.5.2.4.2.200 *BDM/CDM/PDS* assigné pour un courant de défaut élevé

1) Un *BDM/CDM/PDS* assigné pour un courant de défaut élevé (supérieur aux valeurs du Tableau T.28) peut être soumis à l'essai selon le Tableau T.28 uniquement, si les conditions suivantes sont satisfaites:
   a) la série *BDM/CDM/PDS* utilise un *circuit de protection intégrée contre les courts-circuits* pour la conformité à l'essai de court-circuit de courant de défaut normalisé;
   b) le circuit de protection permet d'arrêter un transistor fondé sur un dispositif à semiconducteurs avant une augmentation significative du courant; et
   c) la source du courant de sortie de court-circuit est un dispositif de stockage d'énergie (une batterie de condensateurs, par exemple).
2) L'aptitude du circuit pour ces essais doit dépendre de l'étalonnage du circuit d'essai de court-circuit, T.5.2.4.2.200 3).
3) Étalonnage de court-circuit des circuits d'essai
   a) Généralités
      i) La capacité de courant disponible du circuit ne doit pas être inférieure à la valeur exigée pour les valeurs assignées de court-circuit du *BDM/CDM/PDS*. Les bornes d'alimentation étant mises en court-circuit, la capacité doit être déterminée au point minimal sur l'onde de courant la plus proche, mais pas à une distance inférieure, d'un demi-cycle après la fermeture du circuit en fonction de l'onde de synchronisation de fréquence d'essai. La fréquence des circuits d'essai doit être de 60 Hz ± 12 Hz.
      ii) Pour un circuit en courant alternatif destiné à délivrer au maximum 10 000 A, le courant et le facteur de puissance doivent être déterminés selon T.5.2.4.2.200 3) b). Pour les circuits destinés à délivrer plus de 10 000 A, le courant et le facteur de puissance doivent être déterminés selon T.5.2.4.2.200 3) c) i) à 3) c) viii). Les instruments utilisés pour mesurer les circuits d'essai de plus de 10 000 A doivent satisfaire aux exigences spécifiées en T.5.2.4.2.200 3) c) ix) à 3) c) xix).
   b) Mesurages de courants inférieurs ou égaux à 10 000 A. Les mesurages doivent être réalisés comme suit.
      i) Le courant dans un circuit d'essai triphasé doit être vérifié en calculant la moyenne des valeurs efficaces du premier cycle complet de courant dans chacune des trois phases.
      ii) Le courant dans un circuit d'essai monophasé doit être vérifié en déterminant la valeur efficace du premier cycle complet (voir la Figure T.8) lorsque le circuit est fermé pour générer une forme d'onde de courant essentiellement symétrique.
      iii) La composante alternative ne doit pas être ajoutée à la valeur obtenue lorsque la mesure est réalisée comme cela est indiqué à la Figure T.8.
      iv) Pour obtenir la forme d'onde symétrique souhaitée d'un circuit d'essai monophasé, une fermeture commandée est recommandée, même si des méthodes de fermeture aléatoire peuvent être utilisées.
      v) Le facteur de puissance doit être déterminé en faisant référence à l'onde de tension en circuit ouvert aux deux points zéro adjacents à la moitié du premier cycle de courant complet par transposition à travers une onde de synchronisation adaptée.
      vi) Le facteur de puissance doit être calculé comme étant la moyenne des valeurs obtenues à l'aide de ces deux points zéro de courant, et la tension au neutre doit être utilisée dans le cas d'un circuit triphasé.

c) Mesurages des courants supérieurs à 10 000 A

i) Le courant symétrique en valeur efficace doit être déterminé, avec les bornes d'alimentation mises en court-circuit, en mesurant la composante alternative de l'onde à un demi-cycle (sur la base de l'onde de synchronisation de fréquence d'essai) après le début du court-circuit. Le courant doit être calculé selon la Figure 7 de l'IEEE C37.09-1999.

ii) Pour un circuit d'essai triphasé, le courant symétrique en valeur efficace doit être égal à la moyenne des courants dans les trois phases. Le courant symétrique en valeur efficace de l'une des phases ne doit pas être inférieur à 90 % du courant d'essai exigé.

iii) Le circuit d'essai et ses transitoires doivent être tels que

1) trois cycles (1/20 s) après le début du court-circuit, la composante alternative symétrique du courant n'est pas inférieure à 90 % de la composante alternative symétrique du courant à la fin du premier demi-cycle; ou

2) la composante alternative symétrique du courant au moment auquel le dispositif de protection contre les *surintensités* interrompt le circuit d'essai doit être égale à au moins 100 % de la caractéristique assignée pour laquelle le contrôleur est soumis à l'essai. Dans les circuits triphasés, la composante alternative symétrique du courant des trois phases doit être moyennée.

iv) Le facteur de puissance doit être déterminé un demi-cycle (sur la base de l'onde de synchronisation de fréquence d'essai) après que le court-circuit s'est produit. Le total des ampères asymétriques en valeur efficace doit être mesuré selon T.5.2.4.2.200 3) c) i) et le rapport M_{A} ou M_{M} être calculé comme suit:

Pour les circuits triphasés:

$$M_{\mathrm{A}} = \frac{X}{Y}$$

où

M_{A} représente le rapport triphasé moyen;

X représente les ampères asymétriques en valeur efficace triphasés moyens;

Y représente les ampères symétriques en valeur efficace triphasés moyens.

Pour les circuits monophasés:

$$M_{\mathrm{M}} = \frac{X_{\mathrm{s}}}{Y_{\mathrm{s}}}$$

où

M_{M} représente le rapport monophasé moyen;

X_{s} représente les ampères asymétriques en valeur efficace monophasés moyens;

Y_{s} représente les ampères symétriques en valeur efficace monophasés moyens.

En utilisant M_{A} ou M_{M}, le facteur de puissance doit être déterminé à partir du Tableau T.29.

v) Le facteur de puissance d'un circuit triphasé peut être calculé à l'aide de la fermeture commandée selon laquelle, en fonction des fermetures qui suivent, une phase différente présente des conditions asymétriques maximales. Chaque phase dispose donc du facteur de puissance déterminé à l'aide de la méthode spécifiée pour des circuits monophasés du T.5.2.4.2.200 3) c) iv). Le facteur de puissance du circuit triphasé doit être considéré comme étant égal à la moyenne des facteurs de puissance déterminés pour chacune de phases.

vi) La tension de rétablissement doit être au moins égale à la tension assignée du *BDM/CDM/PDS*. La valeur de crête de la tension de rétablissement dans le premier demi-cycle complet après la coupure et pour les cinq crêtes suivantes successives doit être au moins égale à 1,4 fois la valeur efficace de la tension assignée du contrôleur. Chacune des crêtes ne doit pas se déplacer de plus ±10° électriques par rapport aux valeurs de crête de la tension de rétablissement en circuit ouvert (c'est-à-dire par rapport à sa position normale sur une onde sinusoïdale). La moyenne des valeurs instantanées de la tension de rétablissement de chacun des six premiers demi-cycles mesurés aux points 45 et 135 sur l'onde ne doit pas être inférieure à 85 % de la valeur *efficace* de la tension assignée du *BDM/CDM/PDS*. La valeur instantanée de la tension de rétablissement aux points 45 et 135 de chacun des six premiers demi-cycles ne doit pas être inférieure à 75 % de la valeur *efficace* de la tension assignée du *BDM/CDM/PDS*.

vii) Si, dans un circuit qui utilise une fermeture secondaire, il n'y a pas d'atténuation ou de déphasage du premier cycle complet de l'onde de tension de rétablissement comparée à l'onde de tension secondaire en circuit ouvert avant que le courant ne circule, le mesurage détaillé des caractéristiques de tension de rétablissement indiquées en T.5.2.4.2.200 3) c) vi) ne doit pas être exigé.

viii) Le shunt d'essai utilisé avec la bobine d'inductance dans l'air présentant une résistance négligeable doit être calculé par la formule suivante:

$$R = 167\frac{E}{I}$$

où

R est le shunt d'essai;

E est la tension dans la bobine d'inductance dans l'air;

I est le courant circulant, tel que déterminé par mesurage oscillographique pendant l'étalonnage de court-circuit ou, par proportion, à partir de mesurages de compteur à un certain courant faible.

ix) Pour un circuit en courant alternatif, le courant et le facteur de puissance doivent être déterminés selon T.5.2.4.2.200 3) c) i) à 3) c) vii). Les instruments utilisés pour mesurer les circuits d'essai doivent satisfaire aux exigences du T.5.2.4.2.200 3) c) x) à 3) c) xix).

x) Le galvanomètre d'un oscillographe magnétique utilisé pour enregistrer la tension et le courant pendant l'étalonnage du circuit et pendant l'essai doit présenter une réponse en fréquence plate (±5 %) comprise entre 50 Hz et 1 200 Hz.

Pour les fusibles rapides, les limiteurs de courant ou les protecteurs de moteur contre les courts-circuits, un galvanomètre présentant une réponse en fréquence plate comprise entre 50 Hz et 9 000 Hz ou un oscilloscope peut être utilisé pour obtenir des valeurs exactes de I_p et $I_2 t$.

xi) Les galvanomètres doivent être étalonnés comme cela est spécifié en T.5.2.4.2.200 3) c) xii) à 3) c) xv).

xii) Si un shunt est utilisé pour déterminer les caractéristiques du circuit, ce qui suit doit s'appliquer.

1) Une tension d'étalonnage en courant continu doit en principe être utilisée.

2) La tension appliquée au circuit du galvanomètre de l'oscillographe doit entraîner une déviation du galvanomètre à peu près équivalente à celle qui est prévue lorsque le même circuit du galvanomètre est connecté au shunt et que le courant de court-circuit nominal circule.

3) La tension doit être appliquée de manière à ce que le galvanomètre dévie dans les deux directions.

4) Des étalonnages supplémentaires doivent être réalisés à environ 50 % et 150 % de la tension utilisée pour obtenir la déviation, sauf que si la déviation maximale prévue est inférieure à 150 % (un circuit monophasé fermé symétriquement, par exemple), un autre point d'étalonnage adapté doit être choisi.

5) La sensibilité du circuit du galvanomètre en volts par pouce doit être déterminée à partir de la déviation mesurée dans chaque cas et la moyenne des résultats des six essais être calculée.

6) Les ampères crêtes par pouce doivent être obtenus en divisant la sensibilité par la résistance du shunt.

7) Le facteur de multiplication doit être utilisé pour déterminer le courant symétrique en valeur efficace comme cela est spécifié en T.5.2.4.2.200 3) c) i).

xiii) Si un transformateur de courant est utilisé pour déterminer les caractéristiques du circuit, ce qui suit doit s'appliquer.

1) Un courant alternatif doit être utilisé pour étalonner le circuit du galvanomètre.

2) La valeur du courant appliqué au circuit du galvanomètre doit entraîner une déviation du galvanomètre à peu près équivalente à celle qui est prévue lorsque le même circuit de galvanomètre est connecté au secondaire du transformateur de courant et que le courant de court-circuit nominal circule dans le primaire.

3) Des étalonnages supplémentaires doivent être réalisés à environ 50 % et 150 % du courant utilisé pour obtenir la déviation, sauf que si la déviation maximale prévue est inférieure à 150 % (un circuit monophasé fermé symétriquement, par exemple), un autre point d'étalonnage adapté doit être choisi.

4) La sensibilité du circuit du galvanomètre en ampères par pouce en valeur efficace doit être déterminée dans chaque cas et la moyenne des résultats être calculée.

5) La sensibilité moyenne doit être multipliée par le rapport du transformateur de courant et par 1,4 pour obtenir les ampères de crête par pouce.

6) Cette constante doit être utilisée pour déterminer le courant symétrique en valeur efficace comme cela est spécifié en T.5.2.4.2.200 3) c) i).

xiv) Tous les éléments du galvanomètre utilisés doivent être correctement alignés dans l'oscillographe ou les différences de déplacement doivent être notées et utilisées selon les besoins.

xv) Une tension à onde sinusoïdale de 60 Hz peut être utilisée pour étalonner le circuit du galvanomètre, à l'aide de la méthode générale spécifiée en T.5.2.4.2.200 3) c) xi). Le facteur obtenu doit être multiplié par 1,4.

xvi) La sensibilité des galvanomètres ou la vitesse d'enregistrement doit être suffisante pour fournir un enregistrement à partir duquel les valeurs de tension, de courant et de facteur de puissance peuvent être mesurées avec exactitude. La vitesse d'enregistrement ne doit pas être inférieure à 1 500 mm/s. Des vitesses plus élevées sont recommandées.

xvii) Le circuit d'essai étant réglé pour fournir les valeurs de tension et de courant spécifiées, et avec un shunt (coaxial) non inductif dont il a été déterminé qu'il est adapté à une utilisation en tant que référence connectée dans le circuit, les essais spécifiés en T.5.2.4.2.200 3) c) xviii) et xix) doivent être réalisés pour vérifier l'exactitude des instruments du fabricant.

xviii) Le secondaire étant mis en court-circuit, le transformateur doit être mis sous tension et la tension aux bornes d'essai être observée pour confirmer que le redressement s'est produit, rendant le circuit inacceptable pour les besoins de l'essai, la tension et le courant n'étant pas sinusoïdaux. Six fermetures aléatoires doivent être réalisées pour démontrer que le flux résiduel dans le noyau de transformateur n'entraîne pas de redressement. Si l'essai est réalisé en fermant le circuit secondaire, cette vérification peut être omise, à condition que l'essai ne commence pas avant la mise sous tension du transformateur pendant au moins 2 s si un examen du *BDM/CDM/PDS* d'essai prouve qu'une durée plus longue est exigée.

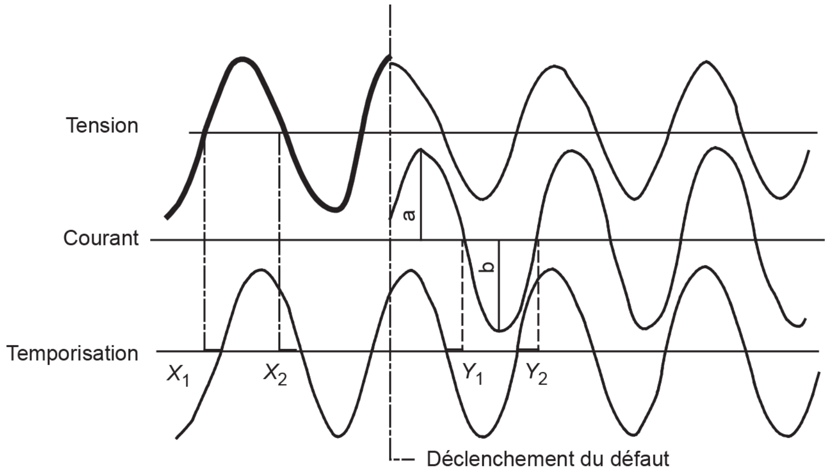
xix) Le circuit étant mis en court-circuit en connectant les bornes d'essai ensemble au moyen d'une barre en cuivre, un circuit monophasé doit être fermé aussi proche que possible de l'angle qui génère une onde de courant avec un décalage maximal.

xx) Le courant de court-circuit et la tension doivent être enregistrés. La tension primaire doit être enregistrée si la fermeture du primaire est utilisée. Le courant mesuré par le shunt de référence doit être dans les limites de 5% de celui mesuré à l'aide des instruments du fabricant, et il ne doit y avoir aucune variation mesurable de relation de phase entre les traces du même courant. La fermeture commandée ne doit pas être exigée pour les circuits polyphasés.

xxi) Si l'exactitude des instruments du fabricant est vérifiée, le shunt coaxial de référence doit être retiré du circuit. Le shunt coaxial de référence ne doit pas être utilisé lors de l'étalonnage final du circuit d'essai ni pendant l'essai des contrôleurs.

Tableau T.29 – Facteur de puissance de court-circuit

Facteur de puissance de court-circuit %	Rapport M_M [a]	Rapport M_A [a]	Facteur de puissance de court-circuit %	Rapport M_M [a]	Rapport M_A [a]
0	1,732	1,394	30	1,130	1,066
1	1,696	1,374	31	1,121	1,062
2	1,665	1,355	32	1,113	1,057
3	1,630	1,336	33	1,105	1,053
4	1,598	1,318	34	1,098	1,049
5	1,568	1,301	35	1,091	1,046
6	1,540	1,285	36	1,084	1,043
7	1,511	1,270	37	1,078	1,039
8	1,485	1,256	38	1,073	1,036
9	1,460	1,241	39	1,068	1,033
10	1,436	1,229	40	1,062	1,031
11	1,413	1,216	41	1,057	1,028
12	1,391	1,204	42	1,053	1,026
13	1,372	1,193	43	1,049	1,024
14	1,350	1,182	44	1,045	1,022
15	1,330	1,171	45	1,041	1,020
16	1,312	1,161	46	1,038	1,019
17	1,294	1,152	47	1,034	1,017
18	1,277	1,143	48	1,031	1,016
19	1,262	1,135	49	1,029	1,014
20	1,247	1,127	50	1,026	1,013
21	1,232	1,119	55	1,015	1,008
22	1,218	1,112	60	1,009	1,004
23	1,205	1,105	65	1,004	1,002
24	1,192	1,099	70	1,002	1,001
[a] Voir T.5.2.4.2.200 3) c) iv).					



$$\text{Courant} = \frac{a+b}{2} \times \text{étalonnage en valeur efficace de l'élément d'instrument}$$

$$\text{Facteur de puissance} = \frac{\text{Cosinus } [(Y_1 + X_1) \times 180] + \text{Cosinus } [(Y_2 + X_2) \times 180]}{2}$$

où

Valeurs X et Y = fractions de la 1/2 distance de cycle dans lequel elles ont lieu

IEC

Figure T.8 – Détermination du courant et du facteur de puissance des circuits de 10 000 A maximum

T.5.2.4.3 Critères d'acceptation

Modification du 5.2.4.3:

1) La *porte* ou le *capot* ne doivent pas être ouverts, et il doit être possible d'ouvrir la *porte* ou le *capot*. Une déformation de l'*enveloppe* doit être considérée comme étant acceptable.
2) Pendant et après l'essai, les circuits *très basse tension (TBT)* accessibles ne doivent pas dépasser leur tension nominale (30 V en courant alternatif/42 V courant continu).
3) Le fusible de terre non temporisé de 30 A, s'il est utilisé, ne doit pas s'être ouvert.
4) Si le générateur de courant électrique constant est utilisé, le courant mesuré maximal ne doit pas dépasser 30 amps en valeur efficace.
5) Le court-circuit ou l'ouverture des jonctions PN dans les dispositifs à semiconducteurs ou la fissuration ou l'ouverture du boîtier à semiconducteurs ou de l'emballage doivent être considérés comme étant acceptables.

T.5.2.4.4 *Essai de tenue* au court-circuit de la *liaison* équipotentielle *de protection* (*essai de type*)

T.5.2.4.5 Essai de court-circuit en *sortie* (*essai de type*)

T.5.2.4.5.1 Conditions de charge

T.5.2.4.5.2 Essai de court-circuit entre les bornes de phase *de* l'accès *de* puissance de sortie (*essai de type*)

T.5.2.4.5.3 Essai de court-circuit entre les bornes de phase *des* accès de puissance *de* sortie et la terre (*essai de type*)

Modification du 5.2.4.5.3:

L'essai de cheminement ne s'applique pas.

Ajout d'un paragraphe supplémentaire à 5.2.4.5:

T.5.2.4.5.200 Généralités

1) Sauf si un marquage est apposé sur le *BDM/CDM/PDS* de manière à limiter le dispositif de protection à des fusibles ou des disjoncteurs à retardement, le *BDM/CDM/PDS* doit être soumis à l'essai tant pour les fusibles que pour les disjoncteurs à retardement.
2) Les fusibles à semiconducteurs peuvent être inclus comme moyen de protection supplémentaire uniquement s'ils font partie intégrante du *BDM/CDM/PDS*.
3) Les essais de court-circuit d'un seul modèle de *BDM/CDM/PDS* doivent être considérés comme étant représentatifs d'autres *BDM/CDM/PDS* de la même série lorsque les conditions suivantes sont satisfaites:
   a) la série *BDM/CDM/PDS* utilise une protection intégrée contre les courts-circuits;
   b) la même protection est utilisée dans toute la série;
   c) le circuit de protection permet d'arrêter le *BDM/CDM/PDS* avant une augmentation significative du courant; et
   d) la source du courant de sortie de court-circuit est un dispositif de stockage d'énergie (une batterie de condensateurs, par exemple).
4) Les critères de sélection des échantillons d'essai doivent inclure ceux qui suivent:
   a) comparaison des caractéristiques assignées de courant coupé limité du fusible et du disjoncteur aux caractéristiques assignées du dispositif à semiconducteurs pour chaque modèle de la série.

      NOTE Les caractéristiques assignées spécifiques à évaluer sont les valeurs maximales de I^2t et de I_p.

   b) renforcement des *composants* et de sous-ensembles (les bus de raccordement, par exemple);
   c) capacité de transfert de chaleur; et
   d) variances dans les valeurs assignées de court-circuit des modèles individuels.

T.5.2.4.5.201 Dispositifs de protection

1) Les dispositifs de protection décrits en T.5.2.4.5.201 2) à 6) doivent être prévus pour l'essai de court-circuit.
2) À moins que les *BDM/CDM/PDS* ne soient marqués de manière à spécifier que la protection du circuit de dérivation contre les courts-circuits doit être assurée uniquement par des fusibles (auquel cas l'essai avec les disjoncteurs n'est pas exigé), ils doivent toujours être soumis à l'essai avec les fusibles et les disjoncteurs. Les fusibles à semiconducteurs peuvent être inclus comme moyen de protection supplémentaire uniquement s'ils font partie intégrante du *BDM/CDM/PDS*.
3) Le dispositif de protection contre les *surintensités* pour cet essai doit être adapté à la protection du circuit de dérivation conformément au Canadian Electrical Code, Part I, et doit satisfaire aux marquages spécifiés en T.6.3.9.6.201 et en T.6.3.9.6.202, selon le cas. Si le marquage du *BDM/CDM/PDS* indique une caractéristique assignée de courant de défaut élevée, le dispositif de protection contre les *surintensités* doit également satisfaire à T.5.2.4.5.201 4).
4) Le fusible utilisé pour les essais de court-circuit spécifiés en 5.2.4.5 doit être comme cela est spécifié par le fabricant et doit être l'un des fusibles suivants.
   a) Un fusible non temporisé ne dépassant pas 600 A assigné à 4 fois le courant de fonctionnement nominal du moteur à pleine charge. Si la valeur calculée du fusible est comprise entre deux caractéristiques assignées normalisées spécifiées en T.5.2.4.5.201 7), un fusible présentant la caractéristique assignée normalisée la plus proche, mais ne dépassant pas 4 fois le courant de fonctionnement nominal du moteur à pleine charge, doit être utilisé. Si la valeur calculée du fusible est inférieure à 1 A, un fusible assigné à 1 A doit être utilisé. Aucun marquage de la dimension du fusible n'est exigé sur le produit.

b) Un fusible non temporisé ne dépassant pas 600 A et dont la dimension est inférieure à celle spécifiée en T.5.2.4.5.201 4) a), mais supérieure 225 % du courant de fonctionnement nominal du moteur à pleine charge, si le produit est marqué de manière à indiquer cette limite de protection.

c) Un fusible temporisé ne dépassant pas 600 A assigné à 225 % au maximum du courant de fonctionnement nominal du moteur à pleine charge, si le produit est marqué de manière à indiquer le niveau de protection et que le dispositif de protection du circuit de dérivation peut, le cas échéant, être de type à temporisation.

d) Un fusible non temporisé ne dépassant pas 601 A à 6000 A assigné à 3 fois le courant de fonctionnement nominal du moteur à pleine charge. Si la valeur calculée du fusible est comprise entre deux caractéristiques assignées normalisées spécifiées en T.5.2.4.5.201 7), un fusible présentant la caractéristique assignée normalisée la plus proche, mais ne dépassant pas 3 fois le courant de fonctionnement nominal du moteur à pleine charge, doit être utilisé. Aucun marquage de la dimension du fusible n'est exigé sur le produit. Pour satisfaire à cette exigence, un fusible assigné à 601 A est considéré comme étant un fusible assigné normalisé.

e) Un fusible non temporisé dont la dimension est plus petite que celle indiquée en T.5.2.4.5.201 4) d) si le produit est marqué de manière à indiquer cette limite de protection.

5) À l’exception de ce qui est exigé en T.5.2.4.5.201 4) b) et e), aucun marquage du type de fusible n'est exigé sur le produit lorsque les essais de court-circuit spécifiés en T.5.2.4.5.201 1), sont réalisés à 5 kA et 10 kA à l'aide de fusibles à cartouche de Classe H non réarmables et non temporisés.

6) Un disjoncteur à retardement utilisé pour l'essai de court-circuit spécifié en T.5.2.4.5.201 1) et 2), doit être tel que spécifié par le fabricant et

a) être assigné à 4 fois le courant de fonctionnement nominal du moteur à pleine charge pour des courants à pleine charge de 100 A au maximum ou à 3 fois le courant de fonctionnement nominal du moteur à pleine charge pour des courants à pleine charge supérieurs à 100 A. Si la valeur calculée du disjoncteur est comprise entre deux caractéristiques assignées normalisées spécifiées en T.5.2.4.5.201 7), un disjoncteur présentant la caractéristique assignée normalisée la plus proche, sans dépasser 4 fois ou 3 fois le courant de fonctionnement nominal du moteur à pleine charge, doit être utilisé. Si la valeur calculée du disjoncteur est inférieure à 15 A, un disjoncteur assigné à 15 A doit être utilisé (aucun marquage de la caractéristique assignée du disjoncteur n'est exigé sur le produit); ou

b) avoir une caractéristique assignée inférieure à celle spécifiée en T.5.2.4.5.201 2)a). Si elle est inférieure à 250 %, le produit doit être marqué de manière à indiquer la limite de protection.

7) Les valeurs assignées en ampères normalisées des fusibles sont 1, 3, 6 et 10. Pour des fusibles supérieurs à 10 A et des disjoncteurs à retardement, les valeurs assignées en ampères normalisées sont 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 700, 800, 1 000, 1 200, 1 600, 2 000, 2 500, 3 000, 4 000, 5 000 et 6 000.

T.5.2.4.6 ***Essai de protection électronique* contre les *surcharges* du *moteur* (*essai de type*)**

T.5.2.4.7 **Essai d’évaluation de la fonctionnalité *du* circuit *(essai de type,* essai *individuel de série, essai sur prélèvement*)**

T.5.2.4.8 **Essai de limitation de *courant* (*essai de type*)**

T.5.2.4.9 Essai de surcharge en *sortie* (*essai de type*)

Ajout d'un paragraphe supplémentaire à 5.2.4.9:

T.5.2.4.9.200 Essai de surcharge des contacts (*essai de type*)

1) À l'exception de ce qui est indiqué en T.5.2.4.9.200 2), un contacteur doit être assigné et approuvé pour le courant maximal, la puissance maximale et la tension maximale que le circuit concerné est en mesure de produire, et il doit être capable d'établir et de couper le courant de charge du circuit.
2) Un contacteur non assigné pour le courant maximal et dont le circuit de bobine est verrouillé ou séquencé de sorte que, dans des conditions normales de fonctionnement, le contacteur n'établisse ni ne coupe le courant de charge, doit être soumis à l'essai aux courant, puissance et tension de surcharge maximaux que le circuit concerné est en mesure de produire. Cinq opérations doivent être réalisées. La durée de cycle des circuits en courant alternatif doit être d'au moins quatre cycles électriques d'activité et de 240 s maximum d'inactivité. Les cycles électriques doivent dépendre de la fréquence de fonctionnement minimale du circuit concerné. Pour les circuits en courant continu, la durée d'activité doit être au moins la plus importante du point a) ou du point b), comme suit:
   a) la durée que met le courant pour atteindre la valeur de surcharge possible maximale; ou
   b) quatre cycles électriques du réseau en courant alternatif duquel est déduite la source en courant continu (si applicable), lorsque les cycles électriques reposent sur la fréquence de fonctionnement minimale du réseau en courant alternatif.

Pour les circuits en courant continu, la durée d'inactivité maximale doit être de 240 s.

T.5.2.4.10 Essai de *défaillance* de composants *(essai de type*)

T.5.2.4.11 Essai de court-circuit des *cartes* de circuit imprimé (*essai de type*)

Ajout à 5.2.4.11:

1) Un fusible non temporisé de Classe CC de 3 A doit être connecté entre le pôle du circuit d'alimentation le moins susceptible de présenter un arc à la terre et l'*enveloppe* extérieure (le cas échéant) et être relié à la terre ou des parties en métal inerte exposées.
2) Les températures doivent être surveillées sur les *composants* les plus susceptibles de surchauffe pendant l'essai.
3) En conséquence des essais, le fusible non temporisé de Classe CC de 3 A relié au circuit de mise à la terre du *BDM/CDM/PDS* ne doit pas s'ouvrir.
4) Si un fil ou une trace de carte de circuit imprimé s'ouvre, celui-ci ou celle-ci doit être électriquement mis(e) en court-circuit et l'essai doit se poursuivre. Cette exigence doit s'appliquer à chaque occurrence.
5) Si l'ouverture d'un *composant* autre qu'un dispositif de protection supplémentaire contre les *surintensités* interrompt le circuit, l'essai doit être répété deux fois à l'aide de nouveaux *composants* si nécessaire.

T.5.2.5 Essais de matériaux

T.5.2.5.1 Généralités

T.5.2.5.2 Essai de formation d'arc à courant *élevé* (*essai de type*)

Remplacement du 5.2.5.2 par les essais spécifiés dans la CSA C22.2 No. 0.17.

T.5.2.5.3 Essai au fil *incandescent* (*essai de type*)

Remplacement du 5.2.5.3 par les essais spécifiés dans la CSA C22.2 No. 0.17.

T.5.2.5.4 Essai d'inflammation au fil chaud *(essai de* type – alternative à l'essai au fil incandescent)

Ajout à 5.2.5.4:

Comme cela est exigé, l'*enveloppe* polymère doit être soumise à l'essai d'allumage avec fil chaud spécifié dans la CSA-C22.2 No. 0.17, et le matériau de l'*enveloppe* ne doit pas s'enflammer dans les 15 s lorsqu'il est soumis à cet essai.

T.5.2.5.5 Essai d'inflammabilité (*essai de type*)

Ajout à 5.2.5.5:

1) les *enveloppes* doivent être soumises à l'essai à la flamme A (15s) de l'Article D.1 de la CSA-C22.2 No. 0.17, ou
2) les *enveloppes* doivent être soumises à l'essai à la flamme B (5 s) de l'Article D.2 de la CSA-C22.2 No. 0.17 et doivent être conformes à T.5.2.5.4.

T.5.2.5.6 Essai des joints scellés *(essai de type*)

T.5.2.5.7 Essai de résistance aux ultraviolets (*UV)* (*essai de type*)

Le paragraphe 5.2.5.7 ne s'applique pas; voir les exigences du 4.12.9.

T.5.2.6 Essais environnementaux (*essais de type*)

T.5.2.7 Essai de pression hydrostatique *(essai* de *type, essai individuel de série*)

T.5.2.8 Essai de champs électromagnétiques (CEM) *(essai de type*)

Le paragraphe 5.2.8 ne s'applique pas.

T.6 Exigences relatives aux informations et au marquage

T.6.1 Généralités

Ajout d'un paragraphe supplémentaire à 6.1:

T.6.1.200 Traduction

Au Canada, les traductions du Tableau T.30 doivent être utilisées.

Tableau T.30 – Traduction des marquages

Référence de l'Article	Marquage en anglais	Marquage en français
T.6.2.1.200 4)	CAUTION: BONDING BETWEEN CONDUITS MUST BE PROVIDED	ATTENTION: LES CONDUITS DOIVENT ÊTRE RELIÉS PAR LA MASSE
6.5.5	WARNING: MORE THAN ONE LIVE CIRCUIT. SEE DIAGRAM	AVERTISSEMENT: PLUS D'UN CIRCUIT EST SOUS TENSION. VOIR SCHÉMA
T.6.3.5.200	OR EQUIVALENT	OU L'ÉQUIVALENT
T.6.3.5.200	WARNING: WHEN MOUNTING ON OR OVER A COMBUSTIBLE SURFACE, A FLOOR PLATE OF AT LEAST 1.43 mm GALVANIZED OR 1.6 mm UNCOATED STEEL EXTENDED AT LEAST 150 mm BEYOND THE EQUIPMENT ON ALL SIDES MUST BE INSTALLED	AVERTISSEMENT: SI L'APPAREIL EST INSTALLÉ SUR UN SOL OU PRÈS D'UNE SURFACE COMBUSTIBLE, UNE PLAQUE DE SOL D'AU MOINS 1,43 mm EN MÉTAL GALVANISÉ OU 1,6 mm EN ACIER NON PLAQUÉ, QUI DÉPASSE D'AU MOINS 150 mm LE POURTOUR DE L'APPAREIL, DOIT ÊTRE INSTALLÉE SOUS CE DERNIER
T.6.2.1.200 Article 3)	TWIST WIRES TOGETHER BEFORE INSERTING IN TERMINAL	RETORDRE LES FILS ENSEMBLE AVANT DE LES INSÉRER DANS LA BORNE
T.6.2.1.200 Article 3)	COPPER WIRES MUST NOT BE MIXED WITH ALUMINUM WIRES IN THE SAME TERMINAL HOLE	NE PAS ENFILER DES CONDUCTEURS EN CUIVRE ET DES CONDUCTEURS EN ALUMINIUM ENSEMBLE DANS UN MÊME TROU DE BORNE
T.6.3.9.6.200	SUITABLE FOR USE ON A CIRCUIT CAPABLE OF DELIVERING NOT MORE THAN ___ RMS SYMMETRICAL AMPERES, ___ V MAXIMUM	CONVIENT AUX CIRCUITS NON SUSCEPTIBLES DE DÉLIVRER PLUS DE ___ AMPÈRES SYMÉTRIQUES EFF., MAXIMUM ___ V
T.6.3.9.6.201	WHEN PROTECTED BY ___ (B) ___ WITH A MAXIMUM RATING OF ___ (C) ___	AVEC UNE PROTECTION PAR ___ (B) ___ DE CALIBRE NOMINAL MAXIMAL DE ___ (C) ___
T.6.3.9.6.201	"fuses" or "a circuit breaker"	«des fusibles» ou «un disjoncteur»
T.6.3.9.6.201	WHEN PROTECTED BY ___ CLASS FUSES	AVEC PROTECTION PAR DES FUSIBLES DE CALIBRE ___
T.6.3.9.6.201	WHEN PROTECTED BY A CIRCUIT BREAKER HAVING AN INTERRUPTING RATING NOT LESS THAN ___ RMS SYMMETRICAL AMPERES, ___ V MAXIMUM	AVEC PROTECTION PAR UN DISJONCTEUR À POUVOIR DE COUPURE NOMINAL D'AU MOINS ___ AMPÈRES SYMÉTRIQUES EFF., MAXIMUM ___ V
T.6.3.9.6.202	ATTENTION THE OPENING OF THE BRANCH-CIRCUIT PROTECTIVE DEVICE MAY BE AN INDICATION THAT A FAULT HAS BEEN INTERRUPTED. TO REDUCE THE RISK OF FIRE OR ELECTRIC SHOCK, CURRENT-CARRYING PARTS AND OTHER COMPONENTS OF THE CONTROLLER SHOULD BE EXAMINED AND REPLACED IF DAMAGED. IF BURNOUT OF THE CURRENT ELEMENT OF AN OVERLOAD RELAY OCCURS, THE COMPLETE OVERLOAD RELAY MUST BE REPLACED	ATTENTION LE DÉCLENCHEMENT DU DISPOSITIF DE PROTECTION DU CIRCUIT DE DÉRIVATION PEUT ÊTRE DÛ À UNE COUPURE QUI RÉSULTE D'UN COURANT DE DÉFAUT. POUR LIMITER LE RISQUE D'INCENDIE OU DE CHOC ÉLECTRIQUE, EXAMINER LES PIÈCES PORTEUSES DE COURANT ET LES AUTRES ÉLÉMENTS DU CONTRÔLEUR ET LES REMPLACER S'ILS SONT ENDOMMAGÉS. EN CAS DE GRILLAGE DE L'ÉLÉMENT TRAVERSÉ PAR LE COURANT DANS UN RELAIS DE SURCHARGE, LE RELAIS TOUT ENTIER DOIT ÊTRE REMPLACÉ
T.6.3.9.6.203	INTEGRAL SOLID STATE SHORT-CIRCUIT PROTECTION DOES NOT PROVIDE BRANCH CIRCUIT PROTECTION. BRANCH CIRCUIT PROTECTION MUST BE PROVIDED IN ACCORDANCE WITH THE CANADIAN ELECTRICAL CODE, PART I	LA PROTECTION INTÉGRÉE CONTRE LES COURTS-CIRCUITS N'ASSURE PAS LA PROTECTION DE LA DÉRIVATION. LA PROTECTION DE LA DÉRIVATION DOIT ÊTRE EXÉCUTÉE CONFORMÉMENT AU CODE CANADIEN DE L'ÉLECTRICITÉ, PREMIÈRE PARTIE.

Référence de l'Article	Marquage en anglais	Marquage en français
T.6.4.202 1)	DANGER HIGH VOLTAGE KEEP OUT OR DANGER: ____ V	DANGER HAUTE TENSION ENTRÉE INTERDITE OU DANGER: ____ V
T.6.4.202 5)	WARNING: FUSES MAY BE ENERGIZED	AVERTISSEMENT: LES FUSIBLES PEUVENT ÊTRE SOUS TENSION
T.6.5.2	WARNING: RISK OF ELECTRIC SHOCK. DANGEROUS VOLTAGE MAY EXIST FOR 5 MINUTES AFTER REMOVING POWER	AVERTISSEMENT: RISQUE DU CHOC ÉLECTRIQUE. UNE TENSION DANGEREUSE PEUT ÊTRE PRÉSENTÉE JUSQU'À 5 MINUTES APRÈS AVOIR COUPÉ L'ALIMENTATION
T.6.3.9.1.1.200	WARNING: RISK OF ELECTRIC SHOCK — HEAT SINK ARE LIVE — DISCONNECT POWER SUPPLY BEFORE SERVICING	AVERTISSEMENT: RISQUE DE CHOC ÉLECTRIQUE – LES DISSIPATEURS THERMIQUES SONT SOUS TENSION – COUPEZ L`ALIMENTATION AVANT D`EFFECTUER LA RÉPARATION
T.6.4.201	TRANSIENT SURGE SUPPRESSION SHALL BE INSTALLED ON THE LINE SIDE OF THIS EQUIPMENT AND SHALL BE RATED _____ V (PHASE TO GROUND), SUITABLE FOR OVERVOLTAGE CATEGORY _____, AND SHALL PROVIDE PROTECTION FOR A RATED IMPULSE WITHSTAND VOLTAGE PEAK OF _____ KV	TRANSITOIRES DOIT SE TROUVER DU CÔTÉ SECTEUR DE CET APPAREILLAGE ET CONVENIR À _____ V (PHASE-TERRE), APPARTENIR À LA CATÉGORIE DE SURTENSION _____, ET RÉSISTER À UNE TENSION DE CHOC DE CRÊTE NOMINALE DE _____ KV

T.6.2 Informations relatives à la sélection

T.6.2.1 Généralités

Ajout d'un paragraphe supplémentaire à 6.2.1:

T.6.2.1.200 Commandes des moteurs ne dépassant pas 500 hp

1) Les *BDM/CDM/PDS* destinés à commander un moteur ne dépassant pas 500 hp doivent, outre les caractéristiques assignées de cheval-vapeur, inclure le courant à pleine charge maximal correspondant à chaque caractéristique assignée.
2) Les *BDM/CDM/PDS* alimentés par plusieurs circuits d'alimentation (de puissance) doivent être accompagnés du marquage exigé pour chaque circuit d'alimentation.

   NOTE Le terme "circuit d'alimentation" n'inclut pas le verrouillage ou le *circuit de commande* assigné à 15 A ou moins.

3) Si plusieurs conducteurs de liaison No. 6 AWG ou plus petits doivent être insérés dans une borne à un seul ou à plusieurs conducteurs qui accepte un éventail de dimensions de conducteur, le marquage RETORDRE LES FILS ENSEMBLE AVANT DE LES INSÉRER DANS LA BORNE doit apparaître à côté de la borne de liaison équipotentielle. Si la borne est adaptée aux conducteurs en cuivre et en aluminium, le marquage supplémentaire NE PAS ENFILER DES CONDUCTEURS EN CUIVRE ET DES CONDUCTEURS EN ALUMINIUM ENSEMBLE DANS UN MÊME TROU DE BORNE ou son équivalent doit également apparaître à côté de la borne de liaison équipotentielle.
4) Une *enveloppe* polymère utilisant des conduits métalliques doit être accompagnée de la formulation suivante (ou un équivalent): ATTENTION: LES CONDUITS DOIVENT ÊTRE RELIÉS PAR LA MASSE.

T.6.2.2 Instructions et marquages relatifs aux *accessoires*

Ajout d'un paragraphe supplémentaire à 6.2.2:

T.6.2.2.200 Kits et *accessoires* de terrain

1) L'identification des kits qui peuvent être installés dans le *BDM/CDM/PDS* doit être marquée sur le *BDM/CDM/PDS*, fournie séparément ou incluse dans les catalogues du fabricant.
2) Le kit ou l'emballage d'unité le plus petit doit être marqué avec son numéro de catalogue (ou un équivalent) et le nom ou la marque du fabricant.
3) L'identification et le nom ou la marque du fabricant doivent être marqués sur le kit du connecteur ou sur son emballage. Les informations détaillant la plage des dimensions de conducteur que le connecteur est destiné à recevoir doivent être marquées sur le kit, son conteneur ou son emballage, le dispositif principal ou son *enveloppe* ou être indiquées sur un document séparé.
4) À moins que l'installation correcte d'un kit ne soit clairement évidente, des instructions de montage doivent être fournies avec le kit ou avec l'équipement de commande industriel, et doivent inclure
   a) une identification claire des parties, *composants* ou sous-ensembles individuels,
   b) des schémas d'interconnexion, si applicable, et
   c) des informations de montage explicites qui décrivent tous les aspects du montage.
5) Les parties et *composants* d'un kit doivent être identifiés, le cas échéant, de manière à assurer une bonne correspondance avec le diagramme d'interconnexion.

T.6.3 Informations pour l’installation et la mise en service

T.6.3.1 Généralités

Ajout d’un paragraphe supplémentaire à 6.3.1:

T.6.3.1.200 Le manuel fourni au format papier ou au format électronique

Le manuel d'installation peut être fourni au format papier ou au format électronique, et il convient de le conserver à portée de main à tout instant avec le dispositif. Les manuels d’installation et de maintenance doivent comporter des informations détaillées sur toutes les connexions nécessaires ainsi qu’un schéma d’interconnexion recommandé.

T.6.3.2 Considérations d’ordre mécanique

T.6.3.3 Environnement

Ajout à 6.3.3:

Lorsque cela est exigé par T.4.4.7.1.3 et T.4.4.7.1.4, le degré de pollution et la catégorie de surtension doivent être marquées à l’emplacement 1 selon le Tableau 48.

T.6.3.4 Manutention et montage

T.6.3.5 *Température* de l'enveloppe

Ajout d’un paragraphe supplémentaire à 6.3.5:

T.6.3.5.200 Surface combustible

Lorsque cela est exigé par 4.6.5.3 et T.4.12.201 12), le *BDM/CDM/PDS* doit être marqué avec la formulation suivante (ou un équivalent):

> AVERTISSEMENT:
>
> SI L'APPAREIL EST INSTALLÉ SUR UN SOL OU PRÈS D'UNE SURFACE COMBUSTIBLE, UNE PLAQUE DE SOL D'AU MOINS 1,43 mm EN MÉTAL GALVANISÉ OU 1,6 mm EN ACIER NON PLAQUÉ, QUI DÉPASSE D'AU MOINS 150 mm LE POURTOUR DE L'APPAREIL, DOIT ÊTRE INSTALLÉE SOUS CE DERNIER.

Il n'est pas nécessaire que ce marquage soit permanent.

T.6.3.6 BDM/CDM de *type ouvert*

T.6.3.7 Connexions

T.6.3.8 Mise en service

T.6.3.9 Exigences de protection

T.6.3.9.1 *Parties accessibles* et *circuits*

T.6.3.9.1.1 Généralités

Ajout de paragraphes supplémentaires à 6.3.9.1.1:

T.6.3.9.1.1.200 Métal inerte

Un dissipateur thermique actif ou une autre partie prise par erreur pour une partie en métal inerte et auxquelles des personnes ont accès doit porter le marquage "AVERTISSEMENT" suivi de "RISQUE DE CHOC ÉLECTRIQUE – LES PLAQUES (OU UN AUTRE TERME DÉCRIVANT LE TYPE DE PARTIE DONT IL S'AGIT) SONT ACTIVES – DÉBRANCHER L'ALIMENTATION AVANT DE PROCÉDER A L'ENTRETIEN", ou un équivalent. Le marquage doit être placé sur la *partie active*.

T.6.3.9.1.1.201 Protection du circuit de commande contre les surintensités

Sauf si la protection du *circuit de commande* contre les *surintensités* est prévue dans le *BDM/CDM/PDS*, un marquage permanent doit être prévu sur le *BDM/CDM/PDS* ou un schéma d'interconnexion être fourni pour indiquer que ce type de protection est exigé.

T.6.3.9.2 Classe de protection

T.6.3.9.3 Circuit de *liaison équipotentielle de protection*

T.6.3.9.4 *Courant de* contact ou courant de fuite élevé

T.6.3.9.5 Compatibilité avec le DDR

T.6.3.9.6 Moyens externes de protection

T.6.3.9.6.1 Généralités

T.6.3.9.6.2 Dispositifs de protection

T.6.3.9.6.3 Protection selon l'IEC 60364-4-41:2005 et l'IEC 60364-4-41:2005/AMD1:2017, Articles 411 ou 415

Le paragraphe 6.3.9.6.3 ne s'applique pas

Ajout de paragraphes supplémentaires à 6.3.9.6:

T.6.3.9.6.200 Courant de court-circuit limité

Le marquage suivant doit être apposé sur le *BDM/CDM/PDS*:

CONVIENT AUX CIRCUITS NON SUSCEPTIBLES DE DÉLIVRER PLUS DE ___ AMPÈRES SYMÉTRIQUES EFF., MAXIMUM ___ V.

La valeur assignée en ampère ne doit pas être supérieure à la valeur pour laquelle le contrôleur a été soumis à l'essai selon 5.2.4.5 ou le Tableau T.28. Le marquage d'un composant ou d'un sous-ensemble doit être apposé en permanence sur le dispositif ou sur une étiquette adhésive permanente amovible.

T.6.3.9.6.201 Dispositifs de protection du circuit de dérivation

Le marquage spécifié en T.6.3.9.6.202 doit être accompagné d'informations supplémentaires, si cela est exigé, comme suit:

a) Le *BDM/CDM/PDS* soumis à l'essai à l'aide de dispositifs de protection du circuit de dérivation assignés à moins de la dimension maximale spécifiée en T.5.2.4.5.201 a) ou d), ou T.5.2.4.5.201 a) doit en outre indiquer: AVEC UNE PROTECTION PAR ___ (B) ___ DE CALIBRE NOMINAL MAXIMAL DE ___ (C) ___, où
   i) (B) représente le type de dispositif de protection contre les *surintensités*, "des fusibles" ou "un disjoncteur"; et
   ii) (C) représente la valeur assignée en ampère maximale du dispositif de protection contre les *surintensités* utilisé pour l'essai de court-circuit spécifié en T.5.2.4.5.201 3).
b) Le *BDM/CDM/PDS* soumis à l'essai selon T.5.2.4.5.201 3) pour l'essai de courant de défaut élevé, doit en outre indiquer
   i) AVEC PROTECTION PAR DES FUSIBLES DE CALIBRE ___; ou
   ii) AVEC PROTECTION PAR UN DISJONCTEUR À POUVOIR DE COUPURE NOMINAL D'AU MOINS ___ AMPÈRES SYMÉTRIQUES EFF., MAXIMUM ___ V.

T.6.3.9.6.202 Courant de défaut disponible élevé

Un *BDM/CDM/PDS* destiné à être utilisé sur des circuits dont les courants de défaut disponibles sont élevés, comme cela est indiqué en T.5.2.4.1.200 et en T.5.2.4.5.201, doit être marqué de la manière suivante: "ATTENTION", suivi de la formulation suivante (ou un équivalent)

LE DÉCLENCHEMENT DU DISPOSITIF DE PROTECTION DU CIRCUIT DE DÉRIVATION PEUT ÊTRE DÛ À UNE COUPURE QUI RÉSULTE D'UN COURANT DE DÉFAUT. POUR LIMITER LE RISQUE D'INCENDIE OU DE CHOC ÉLECTRIQUE, EXAMINER LES PIÈCES PORTEUSES DE COURANT ET LES AUTRES COMPOSANTS DU CONTRÔLEUR ET LES REMPLACER S'ILS SONT ENDOMMAGÉS. EN CAS DE GRILLAGE DE L'ÉLÉMENT TRAVERSÉ PAR LE COURANT DANS UN RELAIS DE SURCHARGE, LE RELAIS TOUT ENTIER DOIT ÊTRE REMPLACÉ.

T.6.3.9.6.203 Protection contre les courts-circuits à semiconducteurs

Le marquage suivant, ou un équivalent, doit être apposé sur un *BDM/CDM/PDS* équipé d'une protection contre les courts-circuits à semiconducteurs selon T.5.2.4.5.200 3):

LA PROTECTION INTÉGRÉE CONTRE LES COURTS-CIRCUITS N'ASSURE PAS LA PROTECTION DE LA DÉRIVATION. LA PROTECTION DE LA DÉRIVATION DOIT ÊTRE EXÉCUTÉE CONFORMÉMENT AU CODE CANADIEN DE L'ÉLECTRICITÉ, PREMIÈRE PARTIE.

T.6.3.9.7 Protection contre la surcharge et la surchauffe du moteur

Ajout de paragraphes supplémentaires à 6.3.9.7:

T.6.3.9.7.200 Relais de surcharge ayant un élément remplaçable traversé par le courant

Si un relais de surcharge ayant un élément remplaçable traversé par le courant est utilisé, il doit satisfaire aux exigences de marquage de la CSA C22.2 No. 14.

T.6.3.9.7.201 Relais de surcharge à réenclenchement automatique

Un *BDM/CDM/PDS* utilisant un relais de surcharge à réenclenchement automatique et fourni avec un schéma d'interconnexion indiquant une commande à 2 fils doit être marqué en permanence de manière à indiquer qu'un moteur relié au circuit peut démarrer.

T.6.3.9.7.202 Moteurs avec protection thermique

Un *BDM/CDM/PDS* destiné à être utilisé uniquement avec des moteurs avec protection thermique doit être marqué de manière à indiquer que les moteurs doivent avoir une protection thermique intégrale.

T.6.3.9.7.203 Connexions pour protection thermique

Un *BDM/CDM/PDS* avec des connexions pour protection thermique dans ou sur les moteurs doit identifier la bonne connexion et les caractéristiques assignées de la charge imposée par le *BDM/CDM/PDS* sur les contacts du protecteur. Les caractéristiques assignées doivent être exprimées en volts et en ampères, mais doivent être en volts et volts-ampères s'il s'agit d'une charge électromagnétique. Le marquage doit également indiquer le courant alternatif ou le courant continu.

T.6.4 Informations pour l’utilisation

T.6.4.1 Généralités

T.6.4.2 Réglage

Ajout d’un paragraphe supplémentaire à 6.4.2:

T.6.4.2.200 Paramètres de *déclenchement* réglables

Les paramètres de *déclenchement* réglables doivent être marqués sur le disjoncteur. Si les désignations de code sont utilisées, un tableau doit être fourni sur le contrôleur de combinaison pour spécifier la valeur assignée en ampère de chaque réglage.

T.6.4.3 Étiquettes, panneaux, symboles et signaux

T.6.4.4 Surface brûlante

T.6.4.5 Marquage des commandes et du dispositif

Ajout de paragraphes supplémentaires à 6.4.5:

T.6.4.5.200 Désignation du fusible

Le marquage doit également indiquer la désignation du fusible, mais peut également inclure les termes OU UN ÉQUIVALENT.

T.6.4.5.201 Porte-fusible

Si un fusible (autre qu'un fusible supplémentaire) est fourni, et si un porte-fusible accepte un fusible avec un courant nominal plus élevé, un marquage spécifiant la dimension maximale du fusible doit être apposé à côté du porte-fusible.

Ajout de paragraphes supplémentaires à 6.4:

T.6.4.200 Plusieurs usines

Si le fabricant produit ou assemble des *BDM/CDM/PDS* dans plusieurs usines, chaque produit fini du *BDM/CDM/PDS* doit porter un marquage distinctif qui l'identifie en tant que produit d'une usine particulière.

T.6.4.201 Parasurtenseur externe

Pour un parasurtenseur externe, le *PDS* doit être marqué de manière visible avec ce qui suit, ou un texte équivalent:

LE PARASURTENSEUR DOIT SE TROUVER DU CÔTÉ SECTEUR DE CET APPAREILLAGE ET CONVENIR À _____ V (PHASE-TERRE), APPARTENIR À LA CATÉGORIE DE SURTENSION _____, ET RÉSISTER À UNE TENSION DE CHOC DE CRÊTE NOMINALE DE _____ KV.

T.6.4.202 Divers

Le cas échéant, le *BDM/CDM/PDS* doit être lisiblement marqué comme suit.

1) Les *portes* et *capots* de compartiments contenant des *composants* haute tension doivent porter un marquage d'avertissement à l'extérieur de la *porte* ou du *capot* d'accès, indiquant "DANGER HAUTE TENSION ENTRÉE INTERDITE" ou "DANGER: ____ V" (avec la *tension système* ou la classe de tension insérée dans l'espace).
2) La commande de déverrouillage manuel externe d'un contacteur à verrouillage doit être marquée de manière à indiquer sa fonction.
3) Un marquage permanent lisible doit être apposé sur les panneaux ou les *portes* donnant accès aux *parties actives dangereuses*, avertissant du danger que fait encourir l'ouverture pendant que les parties sont sous tension.
4) Les barrières destinées à être retirées pendant les opérations courantes de maintenance ou d'entretien (barrières qui doivent être retirées pour remplacer des fusibles ou pour examiner les contacts, par exemple) doivent porter un marquage indiquant que leur réinstallation est exigée.
5) Si le contrôleur est conçu de sorte qu'un fusible du *circuit de commande basse tension* est accessible alors que le CPT ou les transformateurs de potentiel sont sous tension, un avertissement doit être prévu aux abords du porte-fusible: "AVERTISSEMENT" suivi de la déclaration "LES FUSIBLES PEUVENT ÊTRE SOUS TENSION", ou un équivalent.

T.6.5 Informations complémentaires

T.6.5.1 Généralités

T.6.5.2 Décharge de condensateurs

Ajout à 6.5.2:

Le marquage doit être placé à un endroit visible par l'utilisateur avant qu'il n'accède au circuit chargé. Le marquage doit inclure ce qui suit: "AVERTISSEMENT – RISQUE DE CHOC ÉLECTRIQUE", suivi des instructions de décharge du condensateur spécifique ou indiquant la durée de décharge exigée du condensateur jusqu'à un niveau inférieur à 50 V en courant continu.

Article supplémentaire:

T.200 Références normatives IEC remplacées par des normes CSA

Au Canada, les références normatives IEC énumérées dans le Tableau T.31 sont remplacées par les normes CSA ou ANSI indiquées.

Tableau T.31 – Références normatives IEC remplacées par des normes CSA

Titre de la norme IEC	Numéro de la norme IEC	Titre de la norme CSA	Numéro de la norme CSA
Techniques des essais à haute tension	IEC 60034 (toutes les parties)	Motors and Generators Motors with Inherent Overheating Protection	C22.2 No.100 C22.2 No.77
Sécurité des machines – Équipement électrique des machines – Partie 1: Exigences générales	IEC 60204-1:2016, IEC 60204-1:2016/AMD1:2021	Industrial Control Equipment Industrial electrical machinery	C22.2 No. 14 C22.2 No. 301
Sécurité des machines – Équipement électrique des machines – Partie 11: Exigences pour les équipements fonctionnant à des tensions supérieures à 1 000 V en courant alternatif ou 1 500 V en courant continu et ne dépassant pas 36 kV	IEC 60204-11:2018	Medium-voltage AC Contactors, Controllers, and Control Centres	C22.2 No. 253
Technique des essais à haute tension – Partie 1: Définitions et exigences générales	IEC 60060-1:2010	Techniques for High-Voltage Testing	ANSI / IEEE 4
Méthode de détermination des indices de résistance et de tenue au cheminement des matériaux isolants solides	IEC 60112:2020	Evaluation of Properties of Polymeric Materials	C22.2 No. 0.17
Electrical insulating materials – Thermal endurance properties – Part 4-1: Ageing ovens – Single-chamber ovens (disponible en anglais seulement)	IEC 60216-4-1	Evaluation of Properties of Polymeric Materials	C22.2 No. 0.17
Installations électriques à basse tension – Partie 1: Principes fondamentaux, détermination des caractéristiques générales, définitions	IEC 60364-1	Canadian Electrical Code, Part I	C22.1
Installations électriques à basse tension – Partie 4-41: Protection pour assurer la sécurité – Protection contre les chocs électriques	IEC 60364-4-41:2005, IEC 60364-4-41:2005/ AMD1:2017	Canadian Electrical Code, Part I	C22.1
Installations électriques à basse tension – Partie 4-44: Protection pour assurer la sécurité – Protection contre les perturbations de tension et les perturbations électromagnétiques	IEC 60364-4-44:2007, IEC 60364-4-44:2007/ AMD1:2015, IEC 60364-4-44:2007/ AMD2:2018	Canadian Electrical Code, Part I	C22.1
Installations électriques à basse tension – Partie 5-54: Choix et mise en œuvre des matériels électriques – Installations de mise à la terre et conducteurs de protection	IEC 60364-5-54:2011, IEC 60364-5-54:2011/ AMD1:2021	Canadian Electrical Code, Part I	C22.1

Titre de la norme IEC	Numéro de la norme IEC	Titre de la norme CSA	Numéro de la norme CSA
Degrés de protection procurés par les enveloppes (Code IP)	IEC 60529:1989, IEC 60529:1989/AMD1:1999, IEC 60529:1989/AMD2:2013	Degrees of protection provided by enclosures (IP code)	CAN/CSA-C22.2 No. 60529
Coordination de l'isolement des matériels dans les réseaux d'énergie électrique à basse tension – Partie 1: Principes, exigences et essais	IEC 60664-1:2020	Insulation Coordination	C22.2 No.0.2
Coordination de l'isolement des matériels dans les systèmes (réseaux) à basse tension – Partie 3: Utilisation de revêtement, d'empotage ou de moulage pour la protection contre la pollution	IEC 60664-3:2016	Insulation Coordination	C22.2 No.0.2
Coordination de l'isolement des matériels dans les systèmes (réseaux) à basse tension – Partie 4: Considérations sur les contraintes de tension à haute fréquence	IEC 60664-4:2005	Insulation Coordination	C22.2 No.0.2
Essais relatifs aux risques du feu – Partie 2-10: Essais au fil incandescent/chauffant – Appareillage et méthode commune d'essai	IEC 60695-2-10:2021	Evaluation of Properties of Polymeric Materials	C22.2 No. 0.17
Essais relatifs aux risques du feu – Partie 2-11: Essais au fil incandescent/chauffant – Méthode d'essai d'inflammabilité pour produits finis (GWEPT)	IEC 60695-2-11:2021	Evaluation of Properties of Polymeric Materials	C22.2 No. 0.17
Essais relatifs aux risques du feu – Partie 2-13: Essais au fil incandescent/chauffant – Méthode d'essai de température d'allumage au fil incandescent (GWIT) pour matériaux	IEC 60695-2-13:2021	Evaluation of Properties of Polymeric Materials	C22.2 No. 0.17
Essais relatifs aux risques du feu – Partie 10-2: Chaleurs anormales – Essai à la bille	IEC 60695-10-2:2014	Evaluation of Properties of Polymeric Materials	C22.2 No. 0.17
Essais relatifs aux risques du feu – Partie 11-10: Flammes d'essai – Méthodes d'essai horizontal et vertical à la flamme de 50 W	IEC 60695-11-10:2013	Evaluation of Properties of Polymeric Materials	C22.2 No. 0.17
Essais relatifs aux risques du feu – Partie 11-20: Flammes d'essai – Méthode d'essai à la flamme de 500 W	IEC 60695-11-20:2015	Evaluation of Properties of Polymeric Materials	C22.2 No. 0.17
Dispositifs de commande électrique automatiques – Partie 1: Exigences générales	IEC 60730-1:2013, IEC 60730-1:2013/ AMD1:2015, IEC 60730-1:2013/ AMD2:2020	Automatic Electrical Controls for Household and Similar Use — Part 1: General Requirements	CAN/CSA E60730-1-15
Appareillage à basse tension – Partie 4-1: Contacteurs et démarreurs de moteurs – Contacteurs et démarreurs électromécaniques	IEC 60947-4-1:2018	Low-Voltage Switchgear and Controlgear — Part 4-1: Contactors and Motor-Starters — Electromechanical Contactors and Motor-Starters	CAN/CSA-C22.2 No. 60947-4-1

Titre de la norme IEC	Numéro de la norme IEC	Titre de la norme CSA	Numéro de la norme CSA
Appareillage à basse tension – Partie 7-1: Matériels accessoires – Blocs de jonction pour conducteurs en cuivre	IEC 60947-7-1:2009	Low-voltage switchgear and controlgear — Part 7-1: Ancillary equipment — Terminal blocks for copper conductors	CAN/CSA-C22.2 No. 60947-7-1
Appareillage à basse tension – Partie 7-2: Matériels accessoires – Blocs de jonction de conducteur de protection pour conducteurs en cuivre	IEC 60947-7-2:2009	Low-voltage switchgear and controlgear — Part 7-2: Ancillary equipment — Protective conductor terminal blocks for copper conductors	CAN/CSA-C22.2 No. 60947-7-2:
Équipements des technologies de l'audio/vidéo, de l'information et de la communication – Partie 1: Exigences de sécurité	IEC 62368-1:2018	Audio/Video, Information and Communication Technology Equipment — Part 1: Safety Requirements	CAN/CSA-C22.2 No. 62368-1

T.Annex P (normative)

Protection des personnes contre les champs électromagnétiques
pour des fréquences comprises entre 0 Hz et 300 GHz

Modification de l'Annex P:

L'Annex P est informative.

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IEC 60112:2020, *Méthode de détermination des indices de résistance et de tenue au cheminement des matériaux isolants solides*

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[7] Cette publication a été retirée.

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