भारतीय मानक
Indian Standard

IS/IEC 60947-3 : 2020

वोल्टेज स्विचगियर और नियंत्रण

भाग 3 स्विच, डिस्कनेक्टर्स, स्विच-डिस्कनेक्टर और फ्यूज-संयोजन इकाइयां

(दूसरा पुनरीक्षण)

Low-Voltage Switchgear and Controlgear

Part 3 Switches, Disconnectors, Switch-Disconnectors and Fuse-Combination Units

(Second Revision)

ICS 29.120.40; 29.130.20

भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक भवन, 9 बहादुर शाह ज़फर मार्ग, नई दिल्ली - 110002
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI - 110002
www.bis.gov.in www.standardsbis.in

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Low Voltage Switchgear and Controlgear Sectional Committee, ETD 07

NATIONAL FOREWORD

This Indian Standard (Part 3) (Second Revision) which is identical with IEC 60947-3 : 2020 'Low-voltage switchgear and controlgear — Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Low Voltage Switchgear and Controlgear Sectional Committee and approval of the Electrotechnical Division Council.

This standard was first published as IS 13947 (Part 3) : 1993 'Low-voltage switchgear and controlgear — Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units', which was identical to IEC 60947-3 : 1990. It was then superseded by IS/IEC 60947-3 : 1999 which was identical to IEC 60947-3 : 1999. It was later revised in 2018 identical to IEC 60947-3 : 2012. This revision has now been undertaken to align this standard with the latest international practices.

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

a) Addition of critical load current tests for DC switches (*see* **9.3.9**);
b) Addition of requirements for a conditional short-circuit rating for disconnectors, switches;
c) Switch-disconnectors protected by circuit-breakers (*see* **9.3.7.2**);
d) Addition of new categories for high-efficiency motors switching (*see* Annex A);
e) Addition of new Annex E for connection to aluminium conductors; and
f) Addition of new Annex F for power losses measurement.

The text of the IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appears referring to this standard, they should be read as 'Indian Standard'.
b) Comma (,) has been used as a decimal marker, while in Indian Standards the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted, are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60050-441 International electrotechnical vocabulary — Part 441: Switchgear controlgear and fuses	IS 1885 (Part 17) : 1979 Electrotechnical vocabulary: Part 17 Switchgear and controlgear (*first revision*)	Technically equivalent
IEC 60695-2-11 : 2014 Fire hazard testing — Part 2-11: Glowing/hot-wire based test methods — Glow-wire flammability test method for end-products (GWEPT)	IS/IEC 60695-2-11 : 2014 Fire hazard testing: Part 2-11 Glowing/hot-wire based test methods — Glow-wire flammability test method for end-products (GWEPT)	Identical
IEC 60947-1 : 2020 Low-voltage switchgear and controlgear — Part 1: General rules	IS/IEC 60947-1 : 2020 Low — voltage switchgear and controlgear: Part 1 General rules (*second revision*)	Identical
IEC 60947-5-1 : 2016 Low-voltage switchgear and controlgear — Part 5-1: Control circuit devices and switching elements — Electromechanical control circuit devices	IS/IEC 60947-5-1: 2016 Low-voltage switchgear and control gear: Part 5-1 Control circuit devices and switching elements — Electromechanical control circuit devices (*second revision*)	Identical

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 61000-4-2 : 2008 Electromagnetic compatibility (EMC) — Part 4-2: Testing and measurement techniques — Electrostatic discharge immunity test	IS 14700 (Part 4/Sec 2) : 2018 Electromagnetic compatibility (EMC): Part 4 Testing and measurement techniques, Sec 2 Electrostatic discharge immunity test (*second revision*)	Identical
IEC 61000-4-3 : 2006 Electromagnetic compatibility (EMC) — Part 4-3: Testing and measurement techniques — Radiated, radio-frequency, electromagnetic field immunity test	IS 14700 (Part 4/Sec 3) : 2018 Electromagnetic Compatibility (EMC): Part 4 Testing and measurement techniques, Section 24 Test methods for protective devices for HEMP conducted disturbance (*first revision*)	Identical
IEC 61000-4-4 : 2012 Electromagnetic compatibility (EMC) — Part 4-4: Testing and measurement techniques — Electrical fast transient/burst immunity test	IS 14700 (Part 4/Sec 4) : 2018 Electromagnetic compatibility (EMC): Part 4 Testing and measurement techniques, Section 4 Electrical fast transient/burst immunity test (*second revision*)	Identical
IEC 61000-4-5 : 2014 Electromagnetic compatibility (EMC) — Part 4-5: Testing and measurement techniques — Surge immunity test	IS 14700 (Part 4/Sec 5) : 2019 Electromagnetic compatibility (EMC): Part 4 Testing and measurement techniques, Sec 5 Surge immunity test (*first revision*)	Identical
IEC 61000-4-6 : 2013 Electromagnetic compatibility (EMC) — Part 4-6 Testing and measurement techniques — Immunity to conducted disturbances, induced by radio-frequency fields	IS 14700 (Part 4/Sec 6) : 2016 Electromagnetic compatibility (EMC): Part 4 Testing and measurement techniques, Sec 6 Immunity to conducted disturbances, induced by radio — Frequency fields	Identical
IEC 62475 : 2010 High-current test techniques — Definitions and requirements for test currents and measuring systems	IS 16828 : 2018 High — Current test techniques — Definitions and requirements for test currents and measuring systems	Identical
ISO 2859-1 : 1999 Sampling procedures for inspection by attributes — Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection	IS 2500 (Part 1) : 2000 Sampling procedures for inspection by attributes: Part 1 Sampling schemes indexed by acceptance quality limit (AQL) for lot- by-Lot inspection (*third revision*)	Identical
CISPR 32 : 2015 Electromagnetic compatibility of multimedia equipment — Emission requirements	IS/CISPR 32 : 2015 Electromagnetic compatibility of multimedia equipment emission requirements	Identical
IEC 60269 (all parts) Low-voltage fuses	IS/IEC 60269-1 : 2014 Low-voltage fuses: Part 1 General requirements IS/IEC 60269-2 : 2016 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 IS/IEC 60269-2 : 2016 Low-voltage fuses: Part 2 Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application) â€" examples of standardized systems of fuses a to k	Identical

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
	IS/IEC 60269-3 : 2010 Low-voltage fuses: Part 3 Supplementary requirements for fuses for use by unskilled persons (fuses mainly for household and similar applications) â€" examples of standardized systems of fuses a to f	
	IS/IEC/TR 60269-5 : 2014 Low-voltage fuses: Part 5 Guidance for the application of low-voltage fuses	
	IS/IEC 60269-6 : 2010 Low-voltage fuses: Part 6 Supplementary requirements for fuse-links for the protection of solar photovoltaic energy systems	

The technical committee has reviewed the provisions of the following international standards referred in this adopted standard and decided that they are acceptable for use in conjunction with this standard.

International Standard	*Title*
IEC 60034-12 : 2016	Rotating electrical machines — Part 12: Starting performance of single speed three-phase cage induction motors
IEC 60034-30-1 : 2014	Rotating electrical machines — Part 30-1: Efficiency classes of line operated AC motors (IE code)
IEC 60228 : 2004	Conductors of insulated cable
IEC 60417	Graphical symbols for use on equipment
IEC 61545 : 1996	Connecting devices — Devices for the connection of aluminium conductors in clamping units of any material and copper conductors in aluminium bodied clamping units
IEC 62208 : 2011	Empty enclosures for low-voltage switchgear and controlgear assemblies — General requirements
CISPR 11 : 2015	Industrial, scientific and medical equipment — Radio-frequency disturbance characteristics — Limits and methods of measurement

Only English language text has been retained while adopting it in this Indian Standard, and as such the page numbers given here are not the same as in the International Standard.

BIS Certification Marking is applicable to the product covered under this Indian Standard. Details of which is given at National Annex G.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test, shall be rounded off in accordance with IS 2 : 2022 ‘Rules for rounding off numerical values (*second revision*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

CONTENTS

INTRODUCTION

The provisions of the general rules dealt with in IEC 60947-1 are applicable to this document, where specifically called for. Clauses and subclauses, tables, figures and annexes of the general rules thus applicable are identified by reference to the sixth edition of IEC 60947-1:2020, for example, 5.3.4.1 of IEC 60947-1:2020, Table 4 of IEC 60947-1:2020, or Annex A of IEC 60947-1:2020.

Indian Standard

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR

PART 3 SWITCHES, DISCONNECTORS, SWITCH-DISCONNECTORS AND FUSE-COMBINATION UNITS

(Second Revision)

1 Scope

This part of IEC 60947 applies to switches, disconnectors, switch-disconnectors and fuse-combination units and their dedicated accessories to be used in distribution circuits and motor circuits of which the rated voltage does not exceed 1 000 V AC or 1 500 V DC.

NOTE 1 Accessories are interconnecting units, extended terminals, internal coils, auxiliary contacts, motor operator, etc. offered as options with the basic unit.

This document does not apply to equipment coming within the scope of IEC 60947-2, IEC 60947-4-1 and IEC 60947-5-1.

Particular requirements for switches, disconnectors, switch-disconnectors and fuse-combination units for use in photovoltaic (PV) DC applications are given in Annex D.

Specific requirements for LV switchgear intended for the connections of aluminium conductors are given in Annex E.

Guidance on measurement of power loss is provided in Annex F.

This document does not include the additional requirements necessary for electrical apparatus for explosive gas atmospheres.

NOTE 2 Depending on its design, a switch (or disconnector) can be referred to as "a rotary switch (disconnector)", "cam-operated switch (disconnector)", "knife-switch (disconnector)", etc.

NOTE 3 In this document, the word "switch" also applies to the apparatus referred to in French as "commutateurs", intended to modify the connections between several circuits and *inter alia* to substitute a part of a circuit for another.

NOTE 4 In general, throughout this document, switches, disconnectors, switch-disconnectors and fuse-combination units will be referred to as "equipment".

The object of this document is to state:

a) the characteristics of the equipment;
b) the conditions that apply to the equipment with reference to:
    1) operation and behaviour in normal service;
    2) operation and behaviour in case of specified abnormal conditions, e.g. short-circuit;
    3) dielectric properties;
c) the tests for confirming that these conditions have been met and the methods that are adopted for these tests;
d) the information relevant to the marking of the equipment or made available by the manufacturer, e.g. in the catalogue.

Specific items requiring agreement between the user and the manufacturer are identified in Annex B.

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

IEC 60034-12:2016, *Rotating electrical machines – Part 12: Starting performance of single-speed three-phase cage induction motors*

IEC 60034-30-1:2014, *Rotating electrical machines – Part 30-1: Efficiency classes of line operated AC motors (IE code)*

IEC 60228:2004, *Conductors of insulated cable*

IEC 60269 (all parts), *Low-voltage fuses*

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

IEC 60695-2-11:2014, *Fire hazard testing – Part 2-11: Glowing/hot-wire based test methods – Glow-wire flammability test method for end-products (GWEPT)*

IEC 60947-1:2020, *Low-voltage switchgear and controlgear – Part 1: General rules*

IEC 60947-5-1:2016, *Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices*

IEC 61000-4-2:2008, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3:2006, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*
IEC 61000-4-3:2006/AMD1:2007
IEC 61000-4-3:2006/AMD2:2010

IEC 61000-4-4:2012, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-5:2014, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*
IEC 61000-4-5:2014/AMD1:2017

IEC 61000-4-6:2013, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61545:1996, *Connecting devices – Devices for the connection of aluminium conductors in clamping units of any material and copper conductors in aluminium bodied clamping units*

IEC 62208:2011, *Empty enclosures for low-voltage switchgear and controlgear assemblies – General requirements*

IEC 62475:2010, *High-current test techniques – Definitions and requirements for test currents and measuring systems*

ISO 2859-1:1999, *Sampling procedures for inspection by attributes – Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection*
ISO 2859-1:1999/AMD1:2011

CISPR 11:2015, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*
CISPR 11:2015/AMD1:2016

CISPR 32:2015, *Electromagnetic compatibility of multimedia equipment – Emission requirements*

3 Terms, definitions and index of terms

3.1 General

For the purposes of this document, the terms and definitions given in IEC 60050-441 and IEC 60947-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.2 Alphabetical index of terms

S

3.3 General terms

3.3.1
disconnector
mechanical switching device which, in the open position, complies with the requirements specified for the isolating function

Note 1 to entry: A disconnector is capable of opening and closing a circuit when either a negligible current is broken or made, or when no significant change in the voltage across the terminals of each of the poles of the disconnector occurs. It is also capable of carrying currents under normal circuit conditions and carrying, for a specified time, currents under abnormal conditions such as those of short-circuit.

[SOURCE: IEC 60050-441:2000, 441-14-05, modified – Reference to isolating function instead of isolating distance.]

3.3.2
fuse-combination unit
combination of a mechanical switching device and one or more fuses in a composite unit, assembled by the manufacturer or in accordance with his instructions

[SOURCE: IEC 60050-441:2000, 441-14-04, modified – The note has been deleted.]

3.3.3
switch-fuse
switch in which one or more poles have a fuse in series in a composite unit

[SOURCE: IEC 60050-441:2000, 441-14-14]

3.3.3.1
switch-fuse single opening
switch-fuse which provides an interruption in the circuit on one side of the fuse-link only

Note 1 to entry: With this arrangement, safety precautions may be necessary when removing fuse-links.

3.3.3.2
switch-fuse double opening
switch-fuse which provides an interruption in the circuit on both sides of the fuse-link

Note 1 to entry: With this arrangement, safety precautions may be necessary when removing fuse-links.

3.3.4
fuse-switch
switch in which a fuse-link or a fuse-carrier with fuse-link forms the moving contact

[SOURCE: IEC 60050-441:2000, 441-14-17]

3.3.4.1
fuse-switch single opening
fuse-switch which provides an interruption in the circuit on one side of the fuse-link only

Note 1 to entry: With this arrangement, safety precautions may be necessary when removing fuse-links.

3.3.4.2
fuse-switch double opening
fuse-switch which provides an interruption in the circuit on both sides of the fuse-link

Note 1 to entry: With this arrangement, safety precautions may be necessary when removing fuse-links.

3.3.5
disconnector-fuse
disconnector in which one or more poles have a fuse in series in a composite unit

[SOURCE: IEC 60050-441:2000, 441-14-15]

3.3.5.1
disconnector-fuse single opening
disconnector-fuse which provides an opening in the circuit on at least one side of the fuse-link, that satisfies the requirements specified for the isolating function

Note 1 to entry: With this arrangement, safety precautions may be necessary when removing fuse-links.

3.3.5.2
disconnector-fuse double opening
disconnector-fuse which provides an opening in the circuit that satisfies the requirements specified for the isolating function on both sides of the fuse-link

3.3.6
fuse-disconnector
disconnector in which a fuse-link or fuse-carrier with fuse-link forms the moving contact

[SOURCE: IEC 60050-441:2000, 441-14-18]

3.3.6.1
fuse-disconnector single opening
fuse-disconnector which provides an opening in the circuit on at least one side of the fuse-link that satisfies the requirements specified for the isolating function

Note 1 to entry: With this arrangement, safety precautions may be necessary when removing fuse-links.

3.3.6.2
fuse-disconnector double opening
fuse-disconnector which provides an opening in the circuit, that satisfies the requirements specified for the isolating function, on both sides of the fuse-link

3.3.7
switch-disconnector-fuse
switch-disconnector in which one or more poles have a fuse in series in a composite unit

[SOURCE: IEC 60050-441:2000, 441-14-16]

3.3.7.1
switch-disconnector-fuse single opening
switch-disconnector-fuse which provides an interruption in the circuit on at least one side of the fuse-link that satisfies the requirements specified for the isolating function

Note 1 to entry: With this arrangement, safety precautions may be necessary when removing fuse-links.

3.3.7.2
switch-disconnector-fuse double opening
switch-disconnector-fuse which provides an interruption in the circuit on both sides of the fuse-link that satisfies the requirements specified for the isolating function

3.3.8
fuse-switch-disconnector
switch-disconnector in which a fuse-link or a fuse-carrier with fuse-link forms the moving contact

[SOURCE: IEC 60050-441:2000, 441-14-19]

3.3.8.1
fuse-switch-disconnector single opening
fuse-switch-disconnector which provides an interruption in the circuit on at least one side of the fuse-link that satisfies the requirements specified for the isolating function

Note 1 to entry: With this arrangement, safety precautions may be necessary when removing fuse-links.

3.3.8.2
fuse-switch-disconnector double opening
fuse-switch-disconnector which provides an interruption in the circuit on both sides of the fuse-link that satisfies the requirements specified for the isolating function

3.3.9
single pole operated three-pole device
mechanical unit consisting of three individually operable single pole switches and/or disconnecting units according to this document, rated as a complete unit for use in a three-phase system

Note 1 to entry: These mechanical units are intended for power distribution systems where switching and/or isolation of an individual phase may be necessary and they should not be used for the switching of the primary circuit of three-phase equipment.

3.3.10
semi-independent manual operation
operation solely by means of directly applied manual energy such that the manual force is increased up to a threshold value beyond which the independent switching operation is achieved unless deliberately delayed by the operator

4 Classification

4.1 According to the utilization category

See 5.4.

4.2 According to the method of operation

4.2.1 Manually operated equipment

– dependent manual operation (see 3.6.12 of IEC 60947-1:2020);
– independent manual operation (see 3.6.15 of IEC 60947-1:2020);
– semi-independent manual operation (see 3.3.10).

4.2.2 Remotely operated equipment

Under consideration.

4.3 According to suitability for isolation

– suitable for isolation (see 8.1.7 of IEC 60947-1:2020);

– not suitable for isolation.

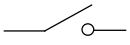
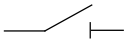
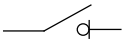
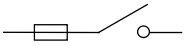
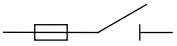
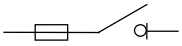
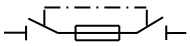
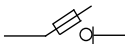
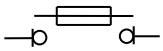
4.4 According to the degree of protection provided

See 8.1.12 of IEC 60947-1:2020.

4.5 Summary of symbols for equipment types

A summary of equipment definitions and relevant diagrams is given in Table 1.

Table 1 – Summary of equipment definitions

Functions		
Making and breaking current	**Isolating**	**Making, breaking and isolating**
Switch 	Disconnector 	Switch-disconnector 
Fuse-combination units		
Switch-fuse single opening [a] 	Disconnector-fuse single opening [a] 	Switch-disconnector-fuse single opening [a] 
Switch-fuse double opening [b] 	Disconnector-fuse double opening 	Switch-disconnector-fuse double opening [b] 
Fuse-switch single opening [a] 	Fuse-disconnector single opening [a] 	Fuse-switch-disconnector single opening [a] 
Fuse-switch double opening [b] 	Fuse-disconnector double opening 	Fuse-switch-disconnector double opening [b] 
NOTE Equipment shown as single opening can comprise multiple openings in series.		
[a] The fuse may be on either side of the contacts of the equipment.		
[b] Depending on the design, breaking may take place on one or both sides of the fuse-link.		

5 Characteristics

5.1 Summary of characteristics

The relevant characteristics from 3.10 of IEC 60947-1:2020 apply, with the following addition.

The characteristics of the equipment shall be stated in terms of the following as applicable:

– type of equipment (see 5.2);

– rated and limiting values for the main circuit (see 5.3);

– utilization category (see 5.4);

– control circuits (see 5.5);

– auxiliary circuits (see 5.6);

5.2 Type of equipment

The following information shall be stated.

– number of poles;
– kind of current (alternating current or direct current);
– in the case of alternating current, number of phases and rated frequency;
– number of positions of the main contacts (if more than two);
– breaking arrangement for fused devices (single opening or double opening).

5.3 Rated and limiting values for the main circuit

5.3.1 General

Rated values are assigned by the manufacturer. They shall be stated in accordance with 5.3.2 to 5.3.7.4 noting that some of the listed values may not apply.

5.3.2 Rated voltages

5.3.2.1 Rated operational voltage (U_e)

Subclause 5.3.1.1 of IEC 60947-1:2020 applies.

5.3.2.2 Rated insulation voltage (U_i)

Subclause 5.3.1.2 of IEC 60947-1:2020 applies.

5.3.2.3 Rated impulse withstand voltage (U_{imp})

Subclause 5.3.1.3 of IEC 60947-1:2020 applies.

5.3.3 Currents

5.3.3.1 General

An equipment is defined by the following currents.

5.3.3.2 Conventional free air thermal current (I_{th})

Subclause 5.3.2.1 of IEC 60947-1:2020 applies.

5.3.3.3 Conventional enclosed thermal current (I_{the})

Subclause 5.3.2.2 of IEC 60947-1:2020 applies.

5.3.3.4 Rated operational current (I_e) or rated operational power

Subclause 5.3.2.3 of IEC 60947-1:2020 applies.

5.3.3.5 Rated uninterrupted current (I_u)

Subclause 5.3.2.4 of IEC 60947-1:2020 applies.

5.3.4 Rated frequency

Subclause 5.3.3 of IEC 60947-1:2020 applies.

5.3.5 Rated duty

5.3.5.1 General

The rated duties considered as normal are as follows.

5.3.5.2 Eight-hour duty

Subclause 5.3.4.1 of IEC 60947-1:2020 applies.

5.3.5.3 Uninterrupted duty

Subclause 5.3.4.2 of IEC 60947-1:2020 applies.

5.3.6 Normal load and overload characteristics

5.3.6.1 Ability to withstand motor switching overload currents

See Annex A.

5.3.6.2 Rated making capacity

Subclause 5.3.5.2 of IEC 60947-1:2020 applies with the following additions.

The rated making capacity is stated by reference to the rated operational voltage and rated operational current and to the utilization category according to Table 4.

Not applicable to AC-20 or DC-20 equipment.

5.3.6.3 Rated breaking capacity

Subclause 5.3.5.3 of IEC 60947-1:2020 applies with the following additions.

The rated breaking capacity is stated by reference to the rated operational voltage and rated operational current and to the utilization category according to Table 4.

Not applicable to AC-20 or DC-20 equipment.

5.3.7 Short-circuit characteristics

5.3.7.1 Rated short-time withstand current (I_{cw})

The rated short-time withstand current of a switch, a disconnector or a switch-disconnector is the value of short-time withstand current, assigned by the manufacturer, that the equipment can carry without any damage under the test conditions of 9.3.6.2.

The value of the rated short-time withstand current shall be not less than twelve times the maximum rated operational current. The duration of the current shall be 1 s, unless otherwise stated by the manufacturer.

For alternating current, the value of the current I_{cw} is the RMS value of the AC component and it is assumed that the highest peak value likely to occur does not exceed n times this RMS value, the factor n being given by Table 16 of IEC 60947-1:2020.

5.3.7.2 Rated short-circuit making capacity (I_{cm})

Subclause 5.3.6.2 of IEC 60947-1:2020 applies with the addition of the following note.

NOTE I_{cm} is not applicable to fused devices.

5.3.7.3 Void

5.3.7.4 Rated conditional short-circuit current (I_q, alternatively I_{cc})

Subclause 5.3.6.4 of IEC 60947-1:2020 applies.

5.4 Utilization category

The utilization categories define the intended applications and are given in Table 2.

Each utilization category is characterized by the values of the currents and voltages, expressed as multiples of the rated operational current and the rated operational voltage, as well as the power-factors or time-constants of the circuit. The conditions for making and breaking given in Table 4 correspond in principle to the applications listed in Table 2.

The designation of utilization categories is completed by the suffix A or B according to whether the intended applications require frequent or infrequent operations (see Table 5).

Utilization categories with suffix B are appropriate for devices which, due to design or application, are only intended for infrequent operation. This could apply, for example, to disconnectors normally only operated to provide isolation for maintenance work or switching devices where the fuse-link blade forms the moving contact.

The distinction between frequent and infrequent operation is based on the manufacturer's rated operation and the number of operating cycles used as a test criterion in Table 5.

For a particular rated operational current I_e, a device will be designated for frequent use (category A) if the manufacturer's declared number of operating cycles is equal to or more than the number of operating cycles indicated in columns 3, 4 and 5 of Table 5.

Table 2 – Utilization categories

Nature of current	Utilization categories		Typical application
	Category A	Category B	
Alternating current	AC-20A [a]	AC-20B [a]	– Connecting and disconnecting under no-load conditions
	AC-21A	AC-21B	– Switching of resistive loads including moderate overloads
	AC-22A	AC-22B	– Switching of mixed resistive and inductive loads, including moderate overloads
	AC-23A	AC-23B	– Switching of motor loads or other highly inductive loads
	AC-23Ae	AC-23Be	– Switching of motor loads with higher locked rotor currents [b]
Direct current	DC-20A [a]	DC-20B [a]	– Connecting and disconnecting under no-load conditions
	DC-21A	DC-21B	– Switching of resistive loads including moderate overloads
	DC-22A	DC-22B	– Switching of mixed resistive and inductive loads, including moderate overloads (e.g. shunt motors)
	DC-23A	DC-23B	– Switching of highly inductive loads (e.g. series motors)

[a] The use of these utilization categories is not permitted in the USA.

[b] Requirements given by asynchronous motors of design NE and HE, according to IEC 60034-12, having extended/higher locked rotor apparent power and current than design N and H respectively, to achieve a higher efficiency class according to the requirements of IEC 60034-30-1.

Category AC-23 includes occasional switching of individual motors. The switching of capacitors or of tungsten filament lamps shall be subject to agreement between manufacturer and user.

The utilization categories referred to in Table 2 and Table 4 do not apply to an equipment normally used to start, accelerate and/or stop individual motors. The utilization categories for such equipment are dealt with in Annex A.

5.5 Control circuits

Subclause 5.5 of IEC 60947-1:2020 applies.

5.6 Auxiliary circuits

Subclause 5.6 of IEC 60947-1:2020 applies.

5.7 Relays and releases

Subclause 5.7 of IEC 60947-1:2020 applies.

5.8 Co-ordination with short-circuit protective devices (SCPD)

Subclause 5.8 of IEC 60947-1:2020 applies.

6 Product information

6.1 Nature of information

Subclause 6.1 of IEC 60947-1:2020 applies as appropriate for a particular design.

6.2 Marking

Product information shall be provided in a durable and legible manner as indicated in Table 3.

Table 3 – Product information

Item	Information	Marking location[a]
1	Indication of the open and close position. If symbols are used, the open position shall be indicated by graphical symbol IEC 60417-5008:2002-10 and the closed position by graphical symbol IEC 60417-5007:2002-10 (see 8.1.6.1 of IEC 60947-1:2020).	Visible
2	Suitability for isolation. The appropriate symbols of Table 1 shall be used.	Visible
3	Additional marking for disconnectors. Devices of utilization category AC-20A, AC-20B, DC-20A, DC-20B and DC-PV0 shall be marked "Do not operate under load" adjacent to these categories, unless the device has interlocking means to prevent such an operation.	Visible
4	Manufacturer's name or trade mark.	Marked
5	Type designation or catalogue reference.	Marked
6	Rated operational currents (or rated powers) with the corresponding rated operational voltage and utilization category (see 5.3.2, 5.3.3 and Clause 5 and/or D.5.4).	Marked
7	Value (or range) of the rated frequency or the indication "DC" (or the symbol  IEC 60417-5031:2002-10).	Marked
8	For fuse-combination units, the fuse type characteristics and maximum rated current and the maximum power loss of the fuse-link.	Marked [b]
9	IEC 60947-3, if the manufacturer claims compliance with this document.	Marked
10	Degree of protection of enclosed equipment (see Annex C of IEC 60947-1:2020).	Marked
11	Terminals shall be identified "load" and "line", unless the connection is immaterial (see 9.3.4.4.1).	Marked
12	Neutral pole terminal, if applicable, shall be identified by the letter "N" (see 8.1.8.4 of IEC 60947-1:2020).	Marked
13	Protective earth terminal shall be identified by the symbol  IEC 60417-5019:2006-08 (see 8.1.10.3 of IEC 60947-1:2020).	Marked
14	Rated insulation voltage.	Literature
15	Rated impulse withstand voltage for equipment suitable for isolation or when determined.	Literature
16	Pollution degree, if different from 3.	Literature
17	Rated duty (see 5.3.5 and Clause A.2).	Literature
18	Rated short-time withstand current and duration, where applicable.	Literature
19	Rated short-circuit making capacity, where applicable.	Literature
20	Rated conditional short-circuit current, where applicable.	Literature
21	Diagram and method of series connecting poles of mechanical switching devices for each operational rating, if applicable.	Literature
22	For switches in accordance with Annex D – appropriate connections to the PV generator and load, if applicable.	Literature
23	"+" and "−" polarities, if applicable.	Marked
24	For devices in accordance with Annex D – suitable for indoor or outdoor use.	Literature

[a] The markings are to be as follows:

Visible: visible from the front when the device is installed as in service in accordance with the manufacturer's instructions and the actuator is accessible and operable;

Marked: marked on the product;

Literature: in the manufacturer's literature.

Information relating to auxiliaries shall be marked on the auxiliary or the product. If space is insufficient the data shall be given in the manufacturer's literature.

[b] Shall be visible after the product is installed in accordance with the manufacturer's instructions but need not necessarily be visible from the front.

6.3 Instructions for installation, operation and maintenance, decommissioning and dismantling

Subclause 6.3 of IEC 60947-1:2020 applies with the following addition.

When hazardous emissions including optical emissions are produced during switching operations, the recommendations as given in the manufacturer's instructions in respect of installation and/or the use of personal protective equipment (PPE) shall be observed.

7 Normal service, mounting and transport conditions

Clause 7 of IEC 60947-1:2020 applies with the replacement of the paragraph under the heading "Standard pollution degree of industrial applications:" in 7.1.3.2 "Pollution degree" with the following:

Unless otherwise stated by the manufacturer, the equipment is intended for installation under environmental conditions of pollution degree 3.

8 Constructional and performance requirements

8.1 Constructional requirements

8.1.1 General

Subclause 8.1 of IEC 60947-1:2020 applies, with the following additions.

Specific requirements for LV switchgear intended for the connections of aluminium conductors is given in Annex E.

When switches and fuse-combination units coming into the scope of this document are normally used to start, accelerate and/or stop an individual motor, they shall also comply with the additional requirements given in Annex A.

The requirements for single pole operated three-pole switches are included in Annex C.

Auxiliary switches fitted to equipment within the scope of this document shall comply with the requirements of IEC 60947-5-1.

8.1.2.2 Glow wire testing

Subclause 8.1.2.2 of IEC 60947-1:2020 applies with the following changes and additions.

Parts of insulating material necessary to retain current-carrying parts in position shall conform to the glow-wire tests of 9.2.2.1 of IEC 60947-1:2020 for test temperatures as follows:

– main current carrying parts: 960 °C.
– auxiliary current carrying parts: 850 °C.

The requirements of 8.1.2.2 of IEC 60947-1:2020 do not apply to parts with a mass lower than 2 g (insignificant mass as defined in 3.14 of IEC 60695-2-11:2014). For products containing a plurality of small parts, the total mass of non-tested parts located in close proximity to each other shall not exceed 10 g. Proximity shall be based on engineering judgment considering the risk of propagation of fire.

8.1.7 Additional requirements for equipment suitable for isolation

8.1.7.1 General

Subclause 8.1.7 of IEC 60947-1:2020 applies with the following additions.

8.1.7.2 Additional constructional requirements

The equipment shall be marked according to Table 3, item 2.

When no indication of the position of the contacts is provided, for example by the actuator or a separate indicator, all the main contacts shall be clearly visible in the open position.

The strength of the actuating mechanism and the reliability of the indication of the open position shall be checked according to 9.2.6. Moreover, when means are provided by the manufacturer to lock the equipment in the open position, locking shall only be possible when the main contacts are in the open position (see 9.2.6).

This requirement does not apply to equipment where the main contact position is visible in the open position and/or the open position is indicated by other means than the actuator.

NOTE Locking in the closed position can be required for particular applications.

The clearance across the open contacts of the same pole when in the open position shall not be less than the minimum clearance given in Table 13 of IEC 60947-1:2020 and shall also comply with the requirements of 8.2.3.2 item 1) b) of IEC 60947-1:2020.

8.1.9 Additional requirements for equipment provided with a neutral pole

Subclause 8.1.9 of IEC 60947-1:2020 applies except the fourth paragraph.

8.2 Performance requirements

8.2.1 Operating conditions

8.2.1.1 General

Subclause 8.2.1.1 of IEC 60947-1:2020 applies with the following additions.

The following requirements apply to fuse-switches, fuse-disconnectors and fuse-switch-disconnectors with a rated short-circuit making capacity exceeding 10 kA and for which the closing operation is by direct manual operation without an interposing mechanism (for dependent and semi-independent manual operation see 3.6.12 of IEC 60947-1:2020 and 3.3.10).

The test speed for the making operations specified in 9.3.7.3 shall be determined as follows.

a) The equipment shall be operated 15 times manually under no-load conditions in accordance with the manufacturer's instructions, 5 times each, by three persons. The velocity of the hand actuator at the instant of contact closure of the last closing contact shall be determined by oscillographic or other appropriate means at any convenient part of the device.

   The point at which the measurement is made and the velocity at the measurement point shall be stated in the test report. The mean velocity shall be determined after deleting the highest and lowest values.

b) The test apparatus shall ensure that the equipment under test fully closes and that there is no impediment to the free closing movement of the device. The actual test speed shall not exceed the mean velocity determined according to a).

The mass of the moving parts of the test apparatus (without the equipment under test) shall be 2 kg ± 10 %.

8.2.1.2 Limits of operation of power operated equipment

Subclause 8.2.1.2 of IEC 60947-1:2020 applies.

8.2.1.3 Limits of operation of under-voltage relays and releases

Subclause 8.2.1.3 of IEC 60947-1:2020 applies.

8.2.1.4 Limits of operation of shunt releases

Subclause 8.2.1.4 of IEC 60947-1:2020 applies.

8.2.2 Temperature-rise

Subclause 8.2.2 of IEC 60947-1:2020 applies with the following addition.

For fuse-combination units, the temperature-rise of the fuse-link contacts during the test according to 9.3.4.2 shall not cause any damage of a nature which impairs the subsequent performance of the equipment in test sequence I.

8.2.3 Dielectric properties

8.2.3.1 General

Subclause 8.2.3 of IEC 60947-1:2020 applies with the following additions.

8.2.3.2 Impulse withstand voltage

Subclause 8.2.3.2 of IEC 60947-1:2020 applies with the following addition.

Clearances across the open contacts of a device not suitable for isolation shall withstand the test voltage given in Table 12 of IEC 60947-1:2020 appropriate to the rated impulse withstand voltage.

8.2.3.3 Power-frequency or DC withstand voltage of the main, auxiliary and control circuits

Subclause 8.2.3.3 c) of IEC 60947-1:2020 applies with the following addition.

For equipment suitable for isolation, maximum values of leakage current are specified for all the test sequences in 9.3.4.6, 9.3.5.4, 9.3.6.5, 9.3.7.5 and 9.3.8.4, respectively.

8.2.4 Ability to make and break under no-load, normal load and overload conditions

8.2.4.1 Making and breaking capacities

The rated making and breaking capacities are stated by reference to the rated operational voltage and rated operational current and to the utilization category according to Table 4.

The test conditions are specified in 9.3.4.4.1.

Table 4 – Verification of rated making and breaking capacities (see 9.3.4.4) – Conditions for making and breaking corresponding to the various utilization categories

Utilization categories		Rated operational current	Making [a]			Breaking			Number of operating cycles [c]
			I/I_e	U/U_e	cos ϕ	I_c/I_e	U_r/U_e	cos ϕ	
AC-20A [b]	AC-20B [b]	All values	–	–	–	–	–	–	
AC-21A	AC-21B	All values	1,5	1,05	0,95	1,5	1,05	0,95	5
AC-22A	AC-22B	All values	3	1,05	0,65	3	1,05	0,65	5
AC-23A	AC-23B	0 < I_e ≤ 100 A	10	1,05	0,45	8	1,05	0,45	5
		100 A < I_e	10	1,05	0,35	8	1,05	0,35	3 [d]
AC-23Ae	AC-23Be	0 < I_e ≤ 100 A	12 [e]	1,05	0,35	8,5	1,05	0,45	5
		100 A < I_e	12 [e]	1,05	0,25	8,5	1,05	0,35	3 [d]
Utilization categories		**Rated operational categories**	I/I_e	U/U_e	L/R ms	I_c/I_e	U_r/U_e	L/R ms	**Number of operating cycles**
DC-20A [b]	DC-20B [b]	All values	–	–	–	–	–	–	
DC-21A	DC-21B	All values	1,5	1,05	1	1,5	1,05	1	5
DC-22A	DC-22B	All values	4	1,05	2,5	4	1,05	2,5	5
DC-23A	DC-23B	All values	4	1,05	15	4	1,05	15	5

Key

I = making current

I_c = breaking current

I_e = rated operational current

U = applied voltage

U_e = rated operational voltage

U_r = power frequency recovery voltage or DC recovery voltage

L/R = time constant of test circuit

[a] For alternating current the making current is expressed by the RMS value of the periodic component of the current.

[b] The use of these utilization categories is not permitted in the USA.

[c] One switching operation without current between each making and breaking operation is allowed, providing it does not alter the time interval between the required operations as defined in 9.3.4.4.1.

[d] In order to cover both AC-21 and AC-22 categories, an increase in the number of operations for AC-23 and AC-23e from 3 to 5 is allowed with the agreement of the manufacturer.

[e] It is at the discretion of the manufacturer to choose any factor of I/I_e between 12 and 13 and the respective cos ϕ given by the following formula:

I_e ≤ 100 A: cos ϕ = 0,1 × I/I_e – 0,85

I_e > 100 A: cos ϕ = 0,1 × I/I_e – 0,95

8.2.4.2 Operational performance

Tests concerning the verification of the operational performance of equipment are intended to verify that the equipment is capable of making and breaking without failure the currents flowing in its main circuit for the intended use.

The number of operating cycles and the test circuit parameters for the operational performance test for the various utilization categories are given in Table 5 and Table 6.

The test conditions are specified in 9.3.5.2.

Table 5 – Verification of operational performance – Number of operating cycles corresponding to the rated operational current

1	2	3	4	5	6	7	8
Rated operational current I_e	Number of operating cycles per hour	Number of operating cycles					
		Alternating and direct current A categories			Alternating and direct current B categories		
		Without current	With current	Total	Without current	With current	Total
$0 < I_e \leq 100$	120	8 500	1 500	10 000	1 700	300	2 000
$100 < I_e \leq 315$	120	7 000	1 000	8 000	1 400	200	1 600
$315 < I_e \leq 630$	60	4 000	1 000	5 000	800	200	1 000
$630 < I_e \leq 2\,500$	20	2 500	500	3 000	500	100	600
$2\,500 < I_e$	10	1 500	500	2 000	300	100	400
The values in the table apply to all utilization categories except AC-20A, AC-20B, DC-20A and DC-20B. These categories shall comply with the total number of operating cycles in columns 5 or 8 without current. Column 2 gives the minimum operating rate. The operating rate for any utilization category may be increased with the consent of the manufacturer.							

Table 6 – Test circuit parameters for Table 5

Utilization categories		Values of the rated operational current I_e	Making [a]			Breaking		
			I/I_e	U/U_e	cos ϕ	I_c/I_e	U_r/U_e	cos ϕ
AC-21A	AC-21B	All values	1	1	0,95	1	1	0,95
AC-22A	AC-22B	All values	1	1	0,8	1	1	0,8
AC-23A	AC-23B	All values	1	1	0,65	1	1	0,65
AC-23Ae	AC-23Be	All values	1	1	0,65	1	1	0,65
			I/I_e	U/U_e	L/R ms	I_c/I_e	U_r/U_e	L/R ms
DC-21A	DC-21B	All values	1	1	1	1	1	1
DC-22A	DC-22B	All values	1	1	2	1	1	2
DC-23A	DC-23B	All values	1	1	7,5	1	1	7,5

Key

I = making current

I_c = breaking current

I_e = rated operational current

U = voltage before make (applied voltage)

U_e = rated operational voltage

U_r = power frequency recovery voltage or DC recovery voltage

L/R = time constant of test circuit

[a] For alternating current, the making current is expressed by the RMS value of the periodic component of the current.

8.2.4.3 Mechanical durability

Subclause 8.2.4.3.1 of IEC 60947-1:2020 applies. Test conditions are specified in 9.5.2.

8.2.4.4 Electrical durability

Subclause 8.2.4.3.2 of IEC 60947-1:2020 applies. Test conditions are specified in 9.5.3.

8.2.5 Ability to make, break or withstand short-circuit currents

The equipment shall be so constructed as to be capable of withstanding, under the conditions specified in this document, the thermal, dynamic and electrical stresses resulting from short-circuit currents.

Short-circuit currents may be encountered during current making, current carrying in the closed position and current interruption.

The ability of the equipment to make, carry and break short-circuit currents is stated in terms of one or more of the following ratings (see also Table 9):

a) rated short-time withstand current (see 5.3.7.1);

b) rated short-circuit making capacity (see 5.3.7.2);

c) rated conditional short-circuit current (see 5.3.7.4).

8.2.6 Void

8.2.7 Additional performance requirements for equipment suitable for isolation

These requirements only apply to equipment with rated operational voltage greater than 50 V.

With the equipment in new condition and the contacts in the open position the equipment shall withstand the dielectric test of 9.3.4.3.

If tests according to 9.3.4.4 and 9.3.5.2 have been made, the equipment in the condition after the tests shall meet the leakage current requirements of 9.3.4.6.

8.2.8 Critical load current performance: DC equipment

The main circuits of equipment shall be capable of making and breaking its critical load current according to 9.3.9.3 and as verified by test sequence VI.

8.2.9 Overload requirements for equipment incorporating fuses

The main circuit of an equipment shall be capable of carrying an overload current according to 9.3.8.2 and shall not cause any damage of a nature which impairs the subsequent performance of the equipment in test sequence V.

8.3 Electromagnetic compatibility (EMC)

8.3.1 General

Subclause 8.3.1 of IEC 60947-1:2020 applies.

8.3.2 Immunity

8.3.2.1 General

Subclause 8.3.2 of IEC 60947-1:2020 applies with the following change and addition.

8.3.2.2 Equipment incorporating electronic circuits

Equipment incorporating electronic circuits (for example fuse-blowing indicator) shall have satisfactory immunity to electromagnetic disturbances (see 9.4.2.1).

For the appropriate tests to verify the compliance with these requirements, see 9.4 of IEC 60947-1:2020. Table 7 below provides the specific immunity performance criteria to be considered.

Table 7 – Immunity tests [a]

Types of test or test description [a]	Basic standard	Test level required	Acceptance criteria (as defined in Table 24 of IEC 60947-1:2020)
Electrostatic discharges	IEC 61000-4-2	Test level in accordance with Table 23 of IEC 60947-1:2020	B
Radiated radio-frequency electromagnetic field	IEC 61000-4-3		A
Electrical fast transient/burst	IEC 61000-4-4		B
Surge	IEC 61000-4-5		B
Conducted disturbances induced by radio-frequency	IEC 61000-4-6		A

[a] A simple rectifier is not sensitive to electromagnetic disturbances in normal service conditions and does not therefore require immunity tests.

8.3.3 Emission

8.3.3.1 Equipment not incorporating electronic circuits

Subclause 8.3.3 of IEC 60947-1:2020 applies.

8.3.3.2 Equipment incorporating electronic circuits

Equipment incorporating electronic circuits (e.g. an electronic fuse-blowing indicator) may generate continuous electromagnetic disturbances.

Emission shall fulfil the requirements of class A, group 1 of CISPR 11 or those of class A of CISPR 32 (see 9.4.3.2). See Table 8.

Table 8 – Emission limits

Ports	Frequency ranges MHz	Limits [d]	Standards
Enclosure [b]	30 to 230 [a]	30 dB (µV/m) quasi peak measured at 30 m distance [c]	CISPR 11
	230 to 1 000 [a]	37 dB (µV/m) quasi peak measured at 30 m distance [c]	Class A – Group 1
AC power	0,15 to 0,5 [a]	79 dB (µV) quasi peak 66 dB (µV) average	or
	0,5 to 5 [a]	73 dB (µV) quasi peak 60 dB (µV) average	CISPR 32
	5 to 30 [a]	73 dB (µV) quasi peak 60 dB (µV) average	Class A

[a] The lower limit should apply at the transition frequency.

[b] Applicable only to mechanical switching devices containing parts which operate at frequencies higher than 9 kHz, e.g. microprocessors.

[c] May also be measured at a 10 m distance using the limits increased by 10 dB, or at a 3 m distance using the limits increased by 20 dB.

[d] These limits have been copied, without alteration, from CISPR 11 and CISPR 32. They are also in accordance with IEC 60947-1:2020.

These limits are given for mechanical switching devices which are used exclusively in an industrial environment. When there exists a likelihood of use outside the industrial environment, the following notice shall be included in the manufacturer's published information.

WARNING

This product has been designed for environment A.
Use of this product in environment B may cause unwanted electromagnetic disturbances in which case the user may be required to take adequate mitigation measures.

9 Tests

9.1 Kinds of test

9.1.1 General

Subclause 9.1.1 of IEC 60947-1:2020 applies.

9.1.2 Type tests

Subclause 9.1.2 of IEC 60947-1:2020 applies. Type tests are given in Table 9.

9.1.3 Routine tests

9.1.3.1 General

Subclause 9.1.3 of IEC 60947-1:2020 applies with the following additions.

The following tests apply:

– mechanical operation test (see 9.1.3.2)

  operation of the switch, disconnector, switch-disconnector or fuse-combination unit during manufacture and/or other routine test may take the place of the tests listed above, provided the same conditions apply and the number of operations is not less than that specified;

– dielectric test (see 9.1.3.3)

  if, by the control of materials and manufacturing processes, the integrity of the dielectric properties has been proven, these tests may be replaced by sampling tests according to a recognized sampling plan (see ISO 2859-1).

9.1.3.2 Mechanical operation test

A test shall be made to verify the correct mechanical operation of the equipment by five closing and opening operations.

9.1.3.3 Dielectric test

The test conditions shall be in accordance with 9.3.3.4.2 of IEC 60947-1:2020. As an alternative, the combined test according to 9.3.3.4.2, item 3), of IEC 60947-1:2020 is allowed. The value of the test voltage shall be in accordance with that given in Table 19 of IEC 60947-1:2020. The duration of the test shall not be less than 1 s and the test voltage shall be applied as follows:

– with the equipment in the open position, between each pair of terminals which are electrically connected together when the equipment is closed;

– with the equipment in the closed position, between each pole and the adjacent pole(s) and between each pole and the frame;
– for equipment incorporating electronic circuits connected to the main poles, with the equipment in the open position, between each pole and the adjacent pole(s) and between each pole and the frame, either on the incoming side or the outgoing side depending on the position of the electronic components.

Alternatively, disconnection of the electronic circuit(s) is permitted during dielectric tests.

9.1.4 Sampling tests

Sampling tests for verification of clearances shall be made according to 9.3.3.4.3 of IEC 60947-1:2020 in accordance with a recognized sampling plan (see ISO 2859-1).

9.1.5 Special tests

Special tests (see 3.8.4 of IEC 60947-1:2020) are specified in 9.5.

9.2 Compliance with constructional requirements

9.2.1 General

Subclause 9.2 of IEC 60947-1:2020 applies with the following additions.

9.2.5 Mechanical and electrical properties of terminals

Subclause 9.2.5 of IEC 60947-1:2020 applies with the following addition.

Where equipment is designed to be provided with different designs of terminals, the tests shall be conducted on every design.

9.2.6 Verification of the effectiveness of indication of the main contact position of equipment suitable for isolation

9.2.6.1 General

Subclause 9.2.6 of IEC 60947-1:2020 applies with the following additions.

9.2.6.2 Condition of equipment for tests

The test of the actuator mechanism and position indicating device shall be conducted as part of test sequence I (see 9.3.4 and Table 11).

If different types of actuators exist, either additional or integral, only one design shall be tested during sequence I. Moreover, the sample representative of the more critical case shall be tested according to 9.3.4.8.

Table 9 – List of type tests applicable to a given equipment

Tests	Switch	Fuse-switch	Switch-fuse	Discon-nector	Discon-nector-fuse	Fuse-discon-nector	Switch-discon-nector	Switch-discon-nector-fuse	Fuse-switch-discon-nector
Temperature-rise [a]	o	o	o	o	o	o	o	o	o
Temperature-rise verification	o	o	o	o	o	o	o	o	o
Dielectric properties	o	o	o	o	o	o	o	o	o
Dielectric verification	o	o	o	o	o	o	o	o	o
Leakage current	–	–	–	o	o	o	o	o	o
Rated making and breaking capacities (overload)	o	o	o	–	–	–	o	o	o
Operational performance	o	o	o	o	o	o	o	o	o
Rated short-time withstand current	o	–	–	o	–	–	o	–	–
Rated short-circuit making capacity	o	–	–	–	–	–	o	–	–
Rated conditional short-circuit current	o	o	o	o	o	o	o	o	o
Strength of actuator mechanism	–	–	–	o	o	o	o	o	o
Overload test	–	o	o	–	o	o	–	o	o
Critical load current test (DC equipment)	o	o	o	–	–	–	o	o	o

Key

o = test

– = no test required

NOTE This list of type tests is for information only, see also footnote [a] in Table 14, Table 15 and Table 16.

[a] Applies to 9.3.3.4 only.

9.3 Performance

9.3.1 General

Performance type tests to which equipment may be submitted according to its kind are listed in Table 9.

9.3.2 Test sequences

Type tests are grouped together in a number of sequences as shown in Table 10.

For each sequence, tests shall be made in the order listed in accordance with the requirements of the appropriate subclause, apart from the temperature-rise test (simplified testing only) and dielectric properties test of test sequence I, which may be conducted on a separate sample.

Table 10 – Overall scheme of test sequences

Sequences	Tests
Test Sequence I: General performance characteristics (see 9.3.4 and Table 11)	Temperature-rise [e f] Dielectric properties [e] Making and breaking capacities [a] Dielectric verification [a] Leakage current [b] Temperature-rise verification Strength of actuator mechanism
Test Sequence II: Operational performance capability (see 9.3.5 and Table 13)	Operational performance Dielectric verification Leakage current [b] Temperature-rise verification
Test Sequence III: Short-circuit performance capability [c] (see 9.3.6 and Table 14)	Short-time withstand current Short-circuit making capacity [a] Dielectric verification Leakage current [b] Temperature-rise verification
Test Sequence IV: Conditional short-circuit current [c] (see 9.3.7, Table 15 and Table 16)	Short-circuit withstand Short-circuit making [a] Dielectric verification Leakage current [b] Temperature-rise verification
Test Sequence V: Overload performance capability [d] (see 9.3.8 and Table 17)	Overload test Dielectric verification Leakage current [b] Temperature-rise verification
Test Sequence VI: Critical load current (DC) performance (see 9.3.9 and Table 20)	Critical load current test Dielectric verification Leakage current [b] Temperature-rise verification

[a] Not applicable to AC-20 or DC-20 equipment. See 5.3.6.2 and 5.3.6.3.

[b] Only required for equipment suitable for isolation of rated voltage greater than 50 V.

[c] Either test sequence III or test sequence IV to be made according to the ratings stated by the manufacturer.

[d] Not required for switches, disconnectors and switch-disconnectors.

[e] May be conducted outside of the sequence, see 9.3.2.

[f] Applies to 9.3.3.4 only.

9.3.3 General test conditions

9.3.3.1 General requirements

Subclause 9.3.2.1 of IEC 60947-1:2020 applies to all type tests as applicable. The equipment at the start of any test sequence shall be in new and clean condition.

The force applied for any opening operation shall not be greater than the test force determined in 9.2.6.2 of IEC 60947-1:2020 and shall be applied in the same manner without shock.

Where doubt exists as to the correct opening operation, no more than three attempts to operate the equipment to the open position are allowed.

In order to reduce multiple testing for the same fundamental design of equipment, the following test requirements may be used.

9.3.3.2 Simplified test for equipment having the same fundamental design

When submitting simultaneously a range of switches, disconnectors, switch-disconnectors or fuse combination units of the same fundamental design, the following variations are permitted provided the equipment complies in all other respects.

9.3.3.3 Requirements for equipment having the same fundamental design

Switches, disconnectors, switch-disconnectors or fuse combination units shall be evaluated with respect to the following criteria during the determination of acceptance as the same fundamental design:

a) the material, finish and dimensions of the current-carrying parts are identical, except for variation in design of terminals and means of fuse attachment;

b) the contact size, material, configuration and method of attachment are identical;

c) the operating mechanism is of the same fundamental design, materials and physical characteristics are identical;

d) the closing and opening speeds of contacts are substantially the same;

e) moulding and insulating materials are identical;

f) method, materials and construction of any arc extinction device are identical.

The following variations are also permitted, provided the simplified test procedure given in 9.3.3.4 is used:

g) utilization category and operational voltage;

h) application for 50 Hz or 60 Hz;

i) three or four pole equipment (switched or non-switched neutral), provided the requirements of 8.1.9 are applicable;

j) design of terminal provided that clearances and creepage distance are not reduced (see 9.2.5 and 9.3.4.3 of this document and also see 8.1.4 of IEC 60947-1:2020;

k) different types of actuators, either additional or integral, provided the requirements for strength of actuator are verified (see 9.2.6) on each type of actuator, one of which during test sequence I;

l) fuse-base contacts of switch-fuses, disconnector-fuses and switch-disconnector-fuses with different types of fuse-links (fuse-link removed only under no-load conditions).

9.3.3.4 Simplified test procedure

The following simplified test procedure shall be used.

a) If equipment having the same fundamental design is marked claiming more than one utilization category and/or more than one operational voltage, the number of test samples may be reduced, providing the tests are conducted under the most severe conditions.

   For short-circuit, making and breaking, and operational performance tests, the conditions are deemed more severe if the following conditions are simultaneously fulfilled:

   – operational rated voltage equal or higher;

   – test current equal or higher;

   – power factor equal or lower;

   – number of operations equal or higher.

b) Tests performed at 50 Hz are deemed to cover 60 Hz applications and vice versa with the following exceptions:

   – temperature-rise test according to 9.3.4.2 for devices having a current greater than 800 A;

NOTE By agreement between manufacturer and user, tests at 50 Hz can be accepted for operation at 60 Hz and vice versa for currents greater than 800 A.

– temperature-rise and operational performance of relays and releases (see 8.2.2 and 8.2.2.7 of IEC 60947-1:2020). Temperature-rise tests of coils shall be performed for each frequency, but only one included in the relevant test sequence, and if separate supplying of coils and other circuits is possible, it is accepted that other circuits remain supplied at 50 Hz.

c) Tests performed on three pole devices are deemed to cover also four pole devices with a non-switched neutral pole, provided a single-phase test on the neutral pole is performed according to 9.3.3.3.4 of IEC 60947-1:2020.

Tests performed on four switched pole devices are deemed to cover also three switched pole devices provided that all poles are identical and the closing and opening speeds of contacts are substantially the same (only the requirements of 8.1.9 are applicable concerning closing and opening of the neutral pole). However, the four switched pole devices shall always be connected in a three-phase arrangement (see Figure 11 of IEC 60947-1:2020).

d) Tests performed with different types of fuse-base contacts.

Where switch-fuses, disconnector-fuses or switch-disconnector-fuses are designed to be provided with different types of fuse-base contacts, temperature-rise tests according to 9.3.4.2 shall be conducted on each type at the corresponding highest fuse rated current.

The type having the maximum temperature-rise among those of the maximum test current shall be used for tests to sequences I, II and V.

Sequence IV shall be conducted on each type of fuse-base contacts whose fuse connecting means are other than bolted connection, at the highest rated conditional short-circuit corresponding current, and, if different, with the type of fuse having the maximum let-through energy at the highest test voltage.

e) Tests performed with different terminal designs.

Where equipment is designed to be provided with different designs of terminal, the requirements and tests according to 9.3.4.2 of this document and 9.2.5 of IEC 60947-1:2020 shall be conducted on each design. These tests can be performed on separate samples.

Where equipment has terminals to be used on plug-on busbars, a test according to 9.3.4.2 shall be carried out. In addition, a test in accordance with 9.3.6.2 or 9.3.7.3.1 a) or 9.3.7.2.1 a), as applicable, shall be performed. Verification of the plugging operation shall be made. The number of operating cycles shall be 50, the cycle being from the connected position to the disconnected position and back to the connected position. The plugging operation test can be performed on a separate sample.

The test is considered to be satisfactory if the equipment remains mechanically operable.

f) When conducting the tests according to 9.3.3.4, items d) and e) the temperature-rise at terminals and accessible parts can be measured. If the temperature-rise limits of accessible parts comply with Table 3 of IEC 60947-1:2020, no further tests of these parts according to 9.3.4.7 are necessary.

Since the intention of the tests according to 9.3.3.4, items d) and e), is to establish the worst case, the values of Table 2 of IEC 60947-1:2020 do not apply.

9.3.3.5 Test quantities

Subclause 9.3.2.2 of IEC 60947-1:2020 applies.

9.3.3.6 DC test current ripple

The DC test current ripple shall comply with the requirements of 6.3.1 of IEC 62475:2010.

9.3.3.7 Evaluation of test results

The behaviour of the equipment during the tests and its condition after the tests are specified in the appropriate test clause.

9.3.3.8 Test reports

Subclause 9.3.2.4 of IEC 60947-1:2020 applies.

9.3.4 Test sequence I: general performance characteristics

9.3.4.1 General

This test sequence applies to the types of equipment listed in Table 11 and comprises the tests according to this table.

9.3.4.2 Temperature-rise

Subclause 9.3.3.3 of IEC 60947-1:2020 applies with the following additions.

Aluminium test conductors equivalent to the copper conductors given in IEC 60947-1 are given in Annex E of this document.

As a minimum, the test shall be carried out at the rated operational current I_e. At the manufacturer's discretion, when I_{th} and/or I_{the} are higher than I_e, the higher value may be used. In the case of an AC-20 or DC-20 rating, the temperature-rise test shall be carried out at I_{th}, or I_{the} if the device is in a specified enclosure. Fuse-combination units shall be fitted with fuse-links having a rated current equal to the conventional thermal current of the combination unit.

The fuse-link shall have a power loss not exceeding the maximum value specified by the equipment manufacturer. The test may be made with a "dummy" fuse-link of essentially similar design to the standardized fuse-link and having the specified power loss.

In the case of tests carried out on a fuse-switch, a fuse-disconnector or a fuse-switch-disconnector where the blades of the fuse-links are part of the make-breaking contacts, fuse-links shall be used.

NOTE For a fuse-switch or a fuse-switch-disconnector where the blades of the fuse-links are part of the make-breaking contacts, dummies or copper links cannot replace the fuse-links due to the fact that the blades of the fuse-links in these devices wear. The wear of the fuse-blades influences the thermal verification according to 9.3.4.7.

Details of the fuse-links used for the test, i.e. the manufacturer's name and reference, the rated current, the power loss of the fuse-link, and the breaking capacity, shall be given in the test report. The type test with the specified fuse-links shall be deemed to cover the use of any other fuse-link having a power loss, at the conventional thermal current of the combination unit, not exceeding the power loss of the fuse-link used for the test.

Table 11 – Test sequence I: general performance characteristics

Tests	Sub-clause No.	Samples [c]	Types of equipment and order of tests					
			Switch	Fuse-switch and switch-fuse	Discon-nector	Discon-nector-fuse and fuse-discon-nector	Switch-discon-nector	Switch-discon-nector-fuse and fuse-switch-discon-nector
Temperature-rise [d, e]	9.3.4.2	A, B, C, F	1	1	1	1	1	1
Dielectric properties [d]	9.3.4.3	A, C, F	2	2	2	2	2	2
Making and breaking capacities	9.3.4.4	A, D	3	3	[a]	[a]	3	3
Dielectric verification	9.3.4.5	A, D	4	4	[a]	[a]	4	4
Leakage current [b]	9.3.4.6	A, D	-	-	3	3	5	5
Temperature-rise verification	9.3.4.7	A, D	5	5	4	4	6	6
Strength of actuator mechanism	9.3.4.8	A, E	-	-	5	5	7	7

[a] This test is not required for disconnectors (AC-20 or DC-20). See 5.3.6.2 and 5.3.6.3.

[b] Test required only for U_e greater than 50 V.

[c] Only tests marked by the same letter shall be applied in sequence to a given sample: "A" is a sample from each fundamental design, chosen from the highest rated current I_e, and if applicable, having the maximum temperature-rise according to 9.3.3.4, item d).

Other samples if applicable:

"B" is a different sample for 60 Hz test, if applicable, according to 9.3.3.4, item b);

"C" are samples of each other terminal design tested at correspondent maximum rated current;

"D" are samples to verify as many combinations of U_e, I_e, AC or DC voltage ratings, to be tested (see 9.3.3.4);

"E" is the extra sample as specified in 9.2.6.2 and can be one of the samples B, C or D;

"F" are samples of every type of fuse-carrier of fuse-combination unit according to 9.3.3.4, item d).

[d] May be conducted outside of the sequence, see 9.3.2.

[e] Applies only to 9.3.3.4.

9.3.4.3 Test of dielectric properties

9.3.4.3.1 General

Subclause 9.3.3.4.1, items 1), 2), 3), 7) and, if applicable, 8) of IEC 60947-1:2020 applies with the following addition.

When, in agreement with the manufacturer, devices are disconnected for the test according to 9.3.3.4.1, item 3) c) of IEC 60947-1:2020, the test report shall state which devices were disconnected for the test. For equipment suitable for isolation (see 4.3) having an operational voltage U_e greater than 50 V, the leakage current shall be measured through each pole with the contacts in the open position, at a test voltage of 1,1 U_e and shall not exceed 0,5 mA.

9.3.4.4 Making and breaking capacities

9.3.4.4.1 General test conditions

Subclause 9.3.3.5 of IEC 60947-1:2020 applies to equipment provided with a neutral pole.

The test values are stated in 8.2.4.1, Table 4, according to the utilization category.

The stated number of make-break operating cycles shall be made with a time interval between close-open cycles of 30 s ± 10 s except that for equipment of conventional thermal current of 400 A or more, the time interval may be increased by agreement between manufacturer and user and the interval shall be stated in the test report.

During each make-break operating cycle, equipment need only stay in the closed position for a period long enough to allow the switching operation to be completed and to enable the current value to be established and the moving parts of the equipment to come to rest. After each operating cycle, the recovery voltage shall be maintained for at least 0,05 s.

For convenience of testing, equipment of utilization categories AC-23A, AC-23Ae, AC-23B and AC-23Be, make-break operating cycles may be replaced, with the agreement of the manufacturer, by the stated number of make cycles followed by the same number of break cycles.

For alternating current, the power-factor of the test circuit shall be determined in accordance with 9.3.4.1.3 of IEC 60947-1:2020. The values shall be in accordance with Table 4.

For direct current, the time-constant of the test circuit shall be determined in accordance with 9.3.4.1.4 of IEC 60947-1:2020. The values shall be in accordance with Table 4.

The test voltage and the load shall be applied to the appropriate terminals of the equipment. For equipment in which a moving contact remains connected to one of the terminals when the equipment is in the open position, this test shall be repeated with the supply and load connections interchanged, unless the terminals are specifically and clearly marked for load and supply.

In the case of tests carried out on a fuse-switch or a fuse-switch-disconnector where the blades of the fuse-links are part of the make-breaking contacts, fuse-links shall be used.

NOTE For a fuse-switch or a fuse-switch-disconnector where the blades of the fuse-links are part of the make-breaking contacts, dummies or copper links cannot replace the fuse-links due to the fact that the blades of the fuse-links in these devices wear. The wear of the fuse-blades influences the thermal verification according to 9.3.4.7.

Details of the fuse-links used for the test, i.e. the manufacturer’s name and reference, the rated current, the power loss of the fuse-link and the breaking capacity, shall be given in the test report.

In the case of tests carried out on a switch-fuse or a switch-disconnector-fuse, fuse-links may be replaced by suitable copper links of dimensions and mass electrically equivalent to those of the fuse-links recommended by the manufacturer. If the test is carried out with fuse-links, at the manufacturer’s discretion, the fuse-link may be changed after each operation. If the fuse-link is changed, the time between operations shall be noted in the report.

9.3.4.4.2 Test circuit

Subclause 9.3.3.5.2 of IEC 60947-1:2020 applies.

9.3.4.4.3 Characteristics of transient recovery voltage

Subclause 9.3.3.5.3 of IEC 60947-1:2020 applies only to utilization categories AC-22, AC-23 and AC-23e. For tests for utilization categories DC-22 and DC-23 the test circuit load may be replaced by a motor producing the specified current and time constant value if agreed between manufacturer and user.

9.3.4.4.4 Behaviour of the equipment during and after making and breaking capacity tests

The equipment shall perform, during the above tests, in such a manner as not to endanger an operator or cause damage to adjacent equipment.

There shall be no permanent arcing or flash-over between poles or between poles and frame and no melting of the fuse in the detection circuit.

The equipment shall remain mechanically operable. Contact welding, such as to prevent an opening operation using normal operating means, is not permitted.

9.3.4.4.5 Condition of equipment after the making and breaking capacity tests

It shall be demonstrated immediately after the test that the equipment will close and open satisfactorily during a no-load close/open operation.

The force required for opening shall not be greater than the test force of 9.2.6.2 of IEC 60947-1:2020 and Table 17 of IEC 60947-1:2020.

A closing operation is considered satisfactory when normal operation of the handle through its full stroke will close the contacts sufficiently for the equipment to be able to carry its rated operational current.

After the test and without maintenance the equipment shall comply with the requirements of 9.3.4.5.

The contacts shall be in a suitable condition to carry the rated operational current without maintenance and shall comply with the temperature-rise verification of 9.3.4.7.

If the equipment is suitable for isolation, it shall comply with 9.3.4.6 and 9.3.4.8.

9.3.4.5 Dielectric verification

After the test according to 9.3.4.4, a test shall be made according to 9.3.3.4.1, item 4) of IEC 60947-1:2020.

9.3.4.6 Leakage current

This test is made only on equipment suitable for isolation of rated operational voltage U_e greater than 50 V. The leakage current shall be checked across the contact gaps as follows:

a) disconnector and switch-disconnector: between load and line terminals;

b) disconnector-fuse, switch-disconnector-fuse, fuse-disconnector and fuse-switch-disconnector single opening: between load and line terminals;

c) disconnector-fuse, switch-disconnector-fuse, fuse-disconnector and fuse-switch-disconnector double opening: (i) between line terminals and the fuse-links; (ii) between load terminals and the fuse-links; and (iii) between load and line terminals.

The value of leakage current, with a test voltage equal to 1,1 times the rated operational voltage of equipment shall not exceed

– 0,5 mA per pole for equipment of utilization category AC-20A, AC-20B, DC-20A or DC-20B;

– 2 mA per pole for equipment of all other utilization categories.

9.3.4.7 Temperature-rise verification

After the tests according to 9.3.4.4, the temperature-rise of the terminals and accessible parts shall be checked according to 9.3.4.2, except that where a utilization category is assigned, the tests are made at the rated operational current I_e of the equipment tested.

The terminals and accessible parts shall not exceed the limiting values stated in Table 12.

Table 12 – Temperature-rise limits for terminals and accessible parts

Description of part [a]	Temperature-rise limit [b] K
Terminals for external connections	80
Manual operating means: – metallic – non-metallic	 25 35
Parts intended to be touched but not hand-held: – metallic – non-metallic	 40 50
Parts which need not be touched for normal operation: – metallic – non-metallic	 50 60
[a] No value is specified for parts other than those listed but no damage shall be caused to adjacent parts of insulating materials. [b] The temperature-rise limits specified are not intended to apply to a new sample but are those applicable to the temperature-rise verifications during the appropriate test sequences specified in Table 10.	

9.3.4.8 Strength of actuator mechanism

Subclause 9.2.6 applies to equipment suitable for isolation.

9.3.5 Test sequence II: operational performance capability

9.3.5.1 General

This test sequence applies to the types of equipment listed in Table 13 and comprises the tests according to this table.

They are made to verify compliance with 8.2.4.2.

Table 13 – Test sequence II: operational performance capability

			Types of equipment and order of tests					
Tests	**Sub-clause No.**	**Samples** [b]	**Switch**	**Fuse-switch and switch-fuse**	**Discon-nector**	**Discon-nector-fuse and fuse-discon-nector**	**Switch-discon-nector**	**Switch-discon-nector-fuse and fuse-switch-discon-nector**
Operational performance	9.3.5.2	A, B	1	1	1	1	1	1
Dielectric verification	9.3.5.3	A, B	2	2	2	2	2	2
Leakage current [a]	9.3.5.4	A, B	–	–	3	3	3	3
Temperature-rise verification	9.3.5.5	A, B	3	3	4	4	4	4

[a] Test required only for U_e greater than 50 V.

[b] "A" is a sample from each fundamental design, chosen from the highest rated current I_e, and if applicable, having the maximum temperature-rise according to 9.3.3.4 d).
"B", if applicable, are samples to verify as many combinations of U_e, I_e, AC or DC voltage ratings, to be tested.

9.3.5.2 Operational performance test

9.3.5.2.1 Test values and conditions

The test values are stated in Table 5 and Table 6, according to the utilization category.

The time interval between Table 5 operating cycles with current and without current and the sequential order of the tests shall be stated in the test report.

During each make-break operating cycle, the equipment need only stay in the closed position for a period long enough to allow the switching operation to be completed and to enable the current value to be established and the moving parts of the equipment to come to rest. After each operating cycle, the recovery voltage shall be maintained for at least 0,05 s.

For alternating current, the power-factor of the test circuit shall be determined in accordance with 9.3.4.1.3 of IEC 60947-1:2020. The values shall be in accordance with Table 6.

For direct current, the time-constant of the test circuit shall be determined in accordance with 9.3.4.1.4 of IEC 60947-1:2020. The values shall be in accordance with Table 6.

9.3.5.2.2 Test circuit

Subclause 9.3.3.5.2 of IEC 60947-1:2020 applies.

9.3.5.2.3 Transient recovery voltage

It is not necessary to adjust the transient recovery voltage.

9.3.5.2.4 Switching overvoltages

Under consideration.

9.3.5.2.5 Behaviour of the equipment during the operational performance test

The equipment shall perform during the above tests in such a manner as not to endanger an operator or cause damage to adjacent equipment.

There shall be no permanent arcing or flash-over between poles or between poles and frame and no melting of the fuse in the detection circuit.

The equipment shall remain mechanically operable. Contact welding, such as to prevent an opening operation using normal operating means, is not permitted.

Some wear on the mechanism and contacts is allowed provided that the equipment functions correctly.

9.3.5.2.6 Condition of the equipment after the operational performance test

It shall be demonstrated immediately after the test that the equipment will close and open satisfactorily during a no-load close/open operation.

The force required for opening shall not be greater than the test force of 9.2.6.2 of IEC 60947-1:2020 and Table 17 of IEC 60947-1:2020.

A closing operation is considered satisfactory when normal operation of the handle through its full stroke will close the contacts sufficiently for the equipment to be able to carry its rated operational current.

After the tests and without maintenance the equipment shall comply with the requirements of 9.3.5.3.

The contacts shall be in a suitable condition to carry the rated operational current without maintenance and shall comply with the temperature-rise verification of 9.3.5.5.

If the equipment is suitable for isolation, it shall comply with 9.3.5.4.

9.3.5.3 Dielectric verification

Subclause 9.3.4.5 applies.

9.3.5.4 Leakage current

Subclause 9.3.4.6 applies.

9.3.5.5 Temperature-rise verification

Subclause 9.3.4.7 applies.

9.3.6 Test sequence III: short-circuit performance capability

9.3.6.1 General

This test sequence applies to the types of equipment listed in Table 14 and comprises the tests according to this table.

This test sequence is not mandatory if a value of rated short-circuit making capacity is not stated by the manufacturer (see 9.3.6.3.1) and test sequence IV (see 9.3.7) is carried out.

The tests are made to verify compliance with 8.2.5.

Table 14 – Test sequence III: short-circuit performance capability

			Types of equipment and order of tests					
Tests	**Sub-clause No.**	**Samples** [d]	**Switch**	**Fuse-switch and switch-fuse**	**Discon-nector**	**Discon-nector-fuse and fuse-discon-nector**	**Switch-discon-nector**	**Switch-disconnector -fuse and fuse- switch-disconnector**
Short-time withstand current	9.3.6.2	A	1		1		1	
Short-circuit making capacity [a] [b]	9.3.6.3	A, B	2		–		2	
Dielectric verification	9.3.6.4	A, B	3	Not applicable	2	Not applicable	3	Not applicable
Leakage current [c]	9.3.6.5	A, B	–		3		4	
Temperature-rise verification	9.3.6.6	A, B	4		4		5	

[a] Test sequence III is not mandatory if test sequence IV is carried out.

[b] Switches and switch-disconnectors not having a rated short-circuit making capacity (see 5.3.7.2) shall meet the requirements of test sequence IV (see Table 16)

[c] Test required only for U_e greater than 50 V.

[d] "A" is a sample from each fundamental design, chosen from the highest I_{cw} current.
"B", if applicable, are samples to verify as many combinations of U_e, I_{cw} or I_{cm}, AC or DC voltage ratings, to be tested.

9.3.6.2 Short-time withstand current test

9.3.6.2.1 Test values and conditions

The test conditions of 9.3.4.3 of IEC 60947-1:2020 apply.

The test current shall be the rated short-time withstand current stated according to 5.3.7.1.

9.3.6.2.2 Test circuit

Subclause 9.3.4.1.2 of IEC 60947-1:2020 applies.

For alternating current, the power-factor of the test circuit shall be in accordance with 9.3.4.1.3 of IEC 60947-1:2020.

For direct current, the time-constant of the test circuit shall be in accordance with 9.3.4.1.4 of IEC 60947-1:2020.

9.3.6.2.3 Calibration of the test circuit

Subclause 9.3.4.1.5 of IEC 60947-1:2020 applies with the following addition at the end of the first paragraph.

*S*ee Figures 3, 4, 5 and 6 of IEC 60947-1:2020.

9.3.6.2.4 Test procedure

The temporary connections B are replaced by the equipment under test and the test current is applied for the specified time with the equipment in the closed position.

9.3.6.2.5 Behaviour of the equipment during the test

The equipment shall perform during the test in such a manner as not to endanger an operator or cause damage to adjacent equipment.

There shall be no permanent arcing or flash-over between poles or between poles and frame and no melting of the fuse in the detection circuit.

The equipment shall remain mechanically operable. Contact welding, such as to prevent an opening operation using normal operating means, is not permitted.

9.3.6.2.6 Conditions of the equipment after the test

It shall be demonstrated, immediately after the test, that the equipment will close and open satisfactorily during a no-load close/open operation.

The force required for opening shall not be greater than the test force of 9.2.6.2 of IEC 60947-1:2020 and Table 17 of IEC 60947-1:2020.

A closing operation is considered satisfactory when normal operation of the handle through its full stroke will close the contacts sufficiently for the equipment to be able to carry its rated operational current.

After the test and without maintenance, if the equipment is a switch or a switch-disconnector, it shall be subjected to the short-circuit making capacity test, 9.3.6.3, as listed in Table 14.

If the equipment is suitable for isolation, it shall comply without maintenance with the dielectric verification of 9.3.6.4.

The contacts of a disconnector shall be in a suitable condition without maintenance to carry the rated operational current and shall comply with the temperature-rise of 9.3.6.6.

9.3.6.3 Short-circuit making capacity test

9.3.6.3.1 Test values and conditions

The test shall be made on the same equipment as for the test of 9.3.6.2 without any maintenance.

The test current shall be that assigned by the manufacturer as stated in 5.3.7.2.

9.3.6.3.2 Test circuit

Subclause 9.3.6.2.2 applies.

9.3.6.3.3 Test circuit calibration

The calibration of the test circuit is carried out by placing temporary connections B of negligible impedance as close as reasonably possible to the terminals provided for connecting the equipment under test.

Depending upon whether the equipment is rated alternating current or direct current, the calibration is made as follows.

a) For alternating current:

   The tests shall be made at the rated frequency of the equipment.

The prospective current shall be applied for at least 0,05 s and its value is the RMS value determined from the calibration record. This value shall be equal to or higher than the specified value in at least one pole.

The average value of all phases shall comply with the tolerances in 9.3.2.2 of IEC 60947-1:2020.

The highest peak value of the prospective current during its first cycle shall be not less than n times the rated short-circuit current, the value of n being as stated in the fourth column of Table 16 of IEC 60947-1:2020.

b) For direct current:

The current shall be applied for the specified time and its mean value, determined from the record, shall be at least equal to the specified value.

If the testing station is unable to make these tests on direct current, they may, if agreed between manufacturer and user, be made on alternating current, provided suitable precautions are taken, for instance, the peak value of current shall not exceed the permissible current.

For equipment having the same rated current for alternating current and direct current. the AC test shall be taken as valid for the DC rating.

9.3.6.3.4 Test procedure

The temporary connections B are replaced by the equipment under test and the equipment shall be closed twice with an interval of approximately 3 min between these operations on a prospective peak current not less than the rated short-circuit making capacity of the equipment. The current or voltage shall be maintained for at least 0,05 s.

The closing mechanism shall be operated so as to simulate service conditions as closely as possible.

9.3.6.3.5 Behaviour of the equipment during the test

The equipment shall perform during the above tests in such a manner as not to endanger an operator or cause damage to adjacent equipment.

There shall not be permanent arcing or flash-over between poles or between poles and frame and no melting of the fuse in the detection circuit.

The equipment shall remain mechanically operable. Contact welding, such as to prevent an opening operation using normal operating means, is not permitted.

9.3.6.3.6 Condition of the equipment after the test

It shall be demonstrated immediately after the test that the equipment will open and close satisfactorily during a no-load open/close operation.

The force required for opening shall not be greater than the test force of 9.2.6.2 of IEC 60947-1:2020 and Table 17 of IEC 60947-1:2020.

A closing operation is considered satisfactory when normal operation of the handle through its full stroke will close the contacts sufficiently for the equipment to be able to carry its rated operational current.

After the test and without maintenance, the equipment shall comply with the dielectric verification of 9.3.6.4.

The contacts shall be in a suitable condition without maintenance to carry the highest rated operational current and shall comply with the temperature-rise verification of 9.3.6.6.

9.3.6.4 Dielectric verification

Subclause 9.3.4.5 applies.

9.3.6.5 Leakage current

Subclause 9.3.4.6 applies, except that the maximum value of leakage current shall not exceed 2 mA per pole for all utilization categories.

9.3.6.6 Temperature-rise verification

Subclause 9.3.4.7 applies.

9.3.7 Test sequence IV: conditional short-circuit current

9.3.7.1 General

This test sequence applies to the types of equipment listed in Table 15 or Table 16, as applicable, and comprises the tests according to the appropriate table.

This test sequence is not mandatory if a value of rated conditional short-circuit current is not stated by the manufacturer and test sequence III (see 9.3.6) is carried out.

For switches, disconnectors and switch-disconnectors the short-circuit protective device of the equipment may be a circuit-breaker or a fuse and shall be arranged on the load side of the equipment under test.

The type of circuit-breaker or fuse shall be that stated by the manufacturer as suitable for the equipment.

Details of the protective device used for the test i.e. manufacturer's name, type designation, rated voltage, current and short-circuit breaking capacity shall be given in the test report.

The type test with the specified protective device shall be deemed to cover the use of any other protective device having a Joule integral (I^2t) and cut-off current at the rated voltage, prospective current and power-factor not exceeding the specified values for the type of protective device used for the test.

The tests are made to verify compliance with 8.2.5.

9.3.7.2 Circuit-breaker protected short-circuit withstand

9.3.7.2.1 Test values and conditions

The circuit-breaker on the load side of the device under test shall be of the rated voltage, rated current and rated breaking capacity deemed suitable by the manufacturer for use with the equipment.

The test voltage to be used shall be equal to 1,05 × U_e, where U_e corresponds to the operational voltage of the device under test.

The test shall be made as follows:

a) withstand test (switches, disconnectors and switch-disconnectors);

   A prospective current corresponding to the rated conditional short-circuit current stated by the manufacturer shall be applied with the equipment in the closed position. The circuit-breaker shall interrupt the current.

b) making test (switches and switch-disconnectors).

Table 15 – Test sequence IV: conditional short-circuit current – circuit-breaker protected

Tests	Sub-clause No.	Sample[c]	Types of equipment and order of tests		
			Switch[a]	Disconnector[a]	Switch-disconnector[a]
Circuit-breaker protected short-circuit withstand	9.3.7.2.1 a)	A, B	1	1	1
Circuit-breaker protected short-circuit making	9.3.7.2.1 b)	A, B	2	-	2
Dielectric verification	9.3.7.4	A, B	3	2	3
Leakage current [b]	9.3.7.5	A, B	-	3	4
Temperature-rise verification	9.3.7.6	A, B	4	4	5

[a] Test sequence IV is not mandatory if test sequence III is carried out (see Table 14).

[b] Test required only for U_e greater than 50 V.

[c] "A" is a sample from each fundamental design, chosen from the highest rated conditional short-circuit current, or if applicable, "A" are samples of each type according to 9.3.3.4 d).
"B", if applicable, are samples to verify as many combinations of U_e, I_{cc}, AC or DC voltage ratings, to be tested.

After the withstand test of item a), all equipment according to Table 15 shall withstand operation "close". The circuit-breaker shall be closed, then the device under test shall be closed. The circuit shall be opened by the circuit-breaker.

9.3.7.2.2 Test circuit

Subclause 9.3.6.2.2 applies.

9.3.7.2.3 Test circuit calibration

Subclause 9.3.6.3.3 applies.

9.3.7.2.4 Test procedure

The closing mechanism of the switch shall be operated according to 8.2.1.1.

The temporary connections are replaced by the equipment under test and the test current applied according to 9.3.7.3.1. The recovery voltage shall be maintained for at least 0,05 s after interruption of the test current by the circuit-breaker.

9.3.7.2.5 Behaviour of the equipment during the test

Subclause 9.3.6.3.5 applies.

9.3.7.2.6 Condition of the equipment after the test

Subclause 9.3.6.3.6 applies.

9.3.7.3 Fuse protected short-circuit withstand

9.3.7.3.1 Test values and conditions

The fuse-links shall be of the rated maximum current and rated breaking capacity deemed suitable by the manufacturer for use with the equipment.

The equipment manufacturer shall supply the fuse-links (see appropriate part of the IEC 60269 series) to be used for the test. Details of the fuse-links used shall be recorded in the test report.

The test voltage to be used shall be equal to 1,05 × U_e, where U_e corresponds to the operational voltage of the device under test.

The test shall be made as follows:

a) Withstand test

A prospective current corresponding to the rated conditional short-circuit current stated by the manufacturer shall be applied with the equipment in the closed position.

b) Making test

After the withstand test of item a), all equipment according to Table 16 shall be fitted with new fuse-links and closed on to the rated conditional short-circuit current.

Table 16 – Test sequence IV: conditional short-circuit current – fuse protected

Tests	Sub-clause No.	Samples[c]	Types of equipment and order of tests					
			Switch[a]	Fuse-switch and switch-fuse	Discon-nector [a]	Discon-nector-fuse and fuse-discon-nector	Switch-discon-nector [a]	Switch-discon-nector-fuse and fuse-switch-discon-nector
Fuse protected short-circuit withstand	9.3.7.3.1 a)	A, B	1	1	1	1	1	1
Fuse protected short-circuit making	9.3.7.3.1 b)	A, B	2	2	–	–	2	2
Dielectric verification	9.3.7.4	A, B	3	3	2	2	3	3
Leakage current [b]	9.3.7.5	A, B	–	–	3	3	4	4
Temperature-rise verification	9.3.7.6	A, B	4	4	4	4	5	5

[a] Test sequence IV is not mandatory if test sequence III is carried out (see Table 14).

[b] Test required only for U_e greater than 50 V.

[c] "A" is a sample from each fundamental design, chosen from the highest rated conditional short-circuit current, or if applicable, "A" are samples of each type according to 9.3.3.4 d).
"B", if applicable, are samples to verify as many combinations of U_e, I_{cc}, AC or DC voltage ratings, to be tested.

9.3.7.3.2 Test circuit

Subclause 9.3.6.2.2 applies.

9.3.7.3.3 Test circuit calibration

Subclause 9.3.6.3.3 applies.

9.3.7.3.4 Test procedure

For fuse-switches, fuse-disconnectors and fuse-switch-disconnectors, the closing mechanism shall be operated according to 8.2.1.1.

The temporary connections are replaced by the equipment under test and the test current applied according to 9.3.7.3.1.

The recovery voltage shall be maintained for at least 0,05 s after interruption of the test current by the fuse.

9.3.7.3.5 Behaviour of the equipment during the test

Subclause 9.3.6.3.5 applies.

9.3.7.3.6 Condition of the equipment after the test

Subclause 9.3.6.3.6 applies.

9.3.7.4 Dielectric verification

Subclause 9.3.4.5 applies.

9.3.7.5 Leakage current

Subclause 9.3.4.6 applies.

9.3.7.6 Temperature-rise verification

Subclause 9.3.4.7 applies.

9.3.8 Test sequence V: overload performance capability

9.3.8.1 General

This test sequence applies to the types of equipment listed in Table 17 and comprises the tests according to the table.

9.3.8.2 Overload test

The equipment shall first be temperature conditioned at room temperature. The test current is 1,6 × I_{the} or 1,6 × I_{th} for a period of 1 h, or until one or more of the fuses blow. If the time is less than 1 h, the time shall be recorded in the test report.

The equipment manufacturer shall supply the fuse-links (see appropriate part of the IEC 60269 series) to be used for the test. Details of the fuse-links used shall be recorded in the test report.

Subclause 9.3.4.2 applies with the exception that no temperatures have to be measured.

Within 3 min to 5 min after the fuse(s) has (have) operated or the period of 1 h is over, the equipment shall be operated once, i.e. opened and closed. The equipment shall not have undergone any impairment hindering such operation. The force to open the equipment shall not be greater than the actuator test force of 9.2.6.2 of IEC 60947-1:2020 and Table 17 of IEC 60947-1:2020.

The time duration of the overload test shall be measured and given in the test report.

9.3.8.3 Dielectric verification

Subclause 9.3.4.5 applies.

9.3.8.4 Leakage current

Subclause 9.3.4.6 applies.

9.3.8.5 Temperature-rise verification

Subclause 9.3.4.7 applies with the addition of the following.

Fuse-links aged during the overload test according to 9.3.8.2 shall be replaced by new fuse-links of the same type and rating.

Table 17 – Test sequence V: overload performance capability

Tests	Sub-clause No.	Samples [b]	Types of equipment and order of tests		
			Fuse-switch and switch-fuse	Disconnector-fuse and fuse-disconnector	Switch-disconnector-fuse and fuse-switch-disconnector
Overload test	9.3.8.2	A	1	1	1
Dielectric verification	9.3.8.3	A	2	2	2
Leakage current [a]	9.3.8.4	A	–	3	3
Temperature-rise verification [c]	9.3.8.5	A	3	4	4

[a] Test required only for U_e greater than 50 V.

[b] "A" is a sample from each fundamental design, chosen from the highest rated current I_e, and if applicable, having the maximum temperature-rise according to 9.3.3.4 d).

[c] By agreement with the manufacturer, the test sequence may be changed so that the temperature-rise verification test follows directly after the overload test, followed by dielectric verification and the leakage current tests, as applicable.

9.3.9 Test sequence VI: critical load current performance of equipment with a DC rating

9.3.9.1 General

This test sequence applies to the equipment listed in Table 20 and comprises the tests according to Table 20.

9.3.9.2 Determination of critical load current

9.3.9.2.1 Test values and conditions

The test to determine the critical load current need not be repeated if it has been determined at a higher time constant.

The test shall be made at the maximum operational DC voltage, U_e, assigned by the manufacturer.

The time constant of the test circuit shall be as given in Table 19.

At the discretion of the manufacturer, a higher value of time constant may be used. The same value of time constant should be used for all tests carried out to determine the critical load current. When a higher value of time constant is used it shall be stated in the report.

The test current values shall be: 1 A, 2 A, 4 A, 8 A, 16 A, 32 A, 63 A, with ±10 % tolerance, up to and including the rated operational current at the highest rated operational voltage. If necessary, the range of the test current shall be extended upwards by applying a 2 times ratio.

The switches, switch-disconnectors and fuse-combination units shall be opened seven times, manually or mechanically at the manufacturer's discretion. During each cycle, the switches, switch-disconnectors and fuse-combination units shall remain closed for a time sufficient to ensure that the full current is established, but not exceeding 2 s.

The number of operating cycles per hour shall be in accordance with Table 18.

In the case of a device where the line and load terminals are identified, all the operations shall be with the supply connected in accordance with the line and load markings. Tests on equipment where the line and load terminals are not marked shall be carried out as follows:

a) with the supply connected to the terminals as determined by the manufacturer, when the manufacturer demonstrates the equipment has a symmetrical contact system and arc control arrangement in respect of the current flow in each pole; or

b) with the first four operations with the supply connected in one direction followed by three operations in the opposite direction on the same sample, when the equipment does not have symmetrical contacts system and arc control arrangement in respect of current flow in each pole.

For each test current, the average arcing time is calculated. If two current flow directions are permitted, the maximum of the two values for this test current is used for further evaluation. If an average arcing time exceeds 1,3 time the value of the average at the rated operational current at the highest rated operational voltage, this is considered a critical current.

NOTE When searching for the critical current, if the value of test current is lower than the previous value of current, a new sample can be used to avoid the effects of remnant magnetism.

If several critical currents are found in this way, the one with the highest arcing time shall be tested.

If no critical value of current is found within these criteria, no further test according to 9.3.9.2.1 is required. At the manufacturer's discretion, the test at each value of current may be carried out on a new sample.

9.3.9.2.2 Test circuit

Subclause 9.3.5.2.2 applies.

9.3.9.2.3 Value of critical load current

The time of the arc extinction during the test shall be recorded and it shall not exceed 1 s.

When all operations are carried out with the current flow in the same direction, for each value of test current the average extinction time for the last six operations is calculated. When the operations are carried out with the current flow in both directions, the average extinction time of the last three operations in each direction shall be calculated. I_{crit} is the current corresponding to the maximum average extinction time. If no critical load current is identified below the rated operational current, the remaining tests in this sequence shall not be carried out.

9.3.9.3 Critical load current performance

The test may be carried out on a new sample. This test sequence is identical to test sequence II (see 9.3.5), except existing Table 5, Table 6 and Table 13 are replaced by Table 18, Table 19 and Table 20, respectively. The test supply shall be connected in accordance with the line-load and polarity markings where applicable. For switches capable of current flow in both directions, the supply shall be connected so as to provide the longest arc duration at the critical load current, as determined in 9.3.9.2.3.

The arcing time during each breaking operation shall not exceed 1 s.

Table 18 – Number of operating cycles corresponding to the critical load current

Category	Rating of the product A	Number of operating cycles per hour [a]	Number of operating cycles at I_{crit}
DC-21, DC-22 and DC-23	$I_e \leq 315$	120	100
	$315 < I_e \leq 630$	60	100
	$630 < I_e \leq 2\,500$	20	100
	$I_e > 2\,500$	10	100
[a] With the agreement of the manufacturer, the number of operating cycles per hour can be increased.			

Table 19 – Test circuit parameters for Table 18

Utilization category	Rated operational current	Making and breaking		
		I	U/U_e	L/R ms
DC-21A, DC-21B	All values	I_{crit}	1	1
DC-22A, DC-22B	All values	I_{crit}	1	2
DC-23A, DC-23B	All values	I_{crit}	1	7,5

Table 20 – Test sequence VI: critical load current performance of equipment with a DC rating

Tests	Sub-clause No.	Samples[b]	Types of equipment and order of tests			
			Switch	Fuse-switch and switch-fuse	Switch-disconnector	Switch-disconnector-fuse and fuse-switch-disconnector
Determination of critical load current	9.3.9.2	A, B	1	1	1	1
Critical load current performance	9.3.9.3	C, D	2	2	2	2
Dielectric verification	9.3.5.3	C, D	3	3	3	3
Leakage current [a]	9.3.5.4	C, D	–	–	4	4
Temperature-rise verification	9.3.5.5	C, D	4	4	5	5

[a] Test required only for U_e greater than 50 V.

[b] "A" and "C" are samples from each fundamental design, chosen from the highest rated current I_e, and if applicable, having the maximum temperature-rise according to 9.3.3.4 d).
"B" and "D", if applicable, are samples to verify as many combinations of U_e, I_e, DC voltage ratings, to be tested.

9.4 Electromagnetic compatibility tests

9.4.1 General

Subclause 9.4 of IEC 60947-1:2020 applies with the following addition.

During tests, the following performance criterion applies:

– unintentional separation or closing of contacts shall not occur.

9.4.2 Immunity

9.4.2.1 Equipment incorporating electronic circuits

The requirements of 8.3.2 of IEC 60947-1:2020 apply. To verify compliance with these requirements, the tests contained in Table 7 shall be conducted.

9.4.3 Emission

9.4.3.1 Equipment not incorporating electronic circuits

No tests are necessary (see 8.3.3.1).

9.4.3.2 Equipment incorporating electronic circuits

The requirements of 8.3.3.2 apply. The limits contained in Table 8 shall be verified by tests.

Measurements shall be made in the operating mode, including grounding conditions, producing the highest emission in the frequency band being investigated which is consistent with normal service conditions (see Clause 6).

Each measurement shall be performed in defined and reproducible conditions.

9.5 Special tests

9.5.1 Mechanical and electrical durability

Resistance to mechanical and/or electrical wear is demonstrated by the operational performance test detailed in 9.3.5.2.

Where abnormal service conditions are expected (see also note to 8.2.4.3.1 of IEC 60947-1:2020), the following tests detailed in 9.5.2 and 9.5.3 may be necessary.

9.5.2 Mechanical durability

The mechanical durability test (see 8.2.4.3 and 9.1.5), where required, is made in accordance with the appropriate requirements of 9.3.5.2, except that for equipment suitable for isolation, the maximum value of leakage current shall not exceed 6 mA per pole for all utilization categories.

The total number of operating cycles shall be as declared by the manufacturer.

9.5.3 Electrical durability

The electrical durability test (see 8.2.4.4 and 9.1.5), where required, is made in accordance with the appropriate requirements of 9.3.5.2, except that for equipment suitable for isolation, the maximum value of leakage current shall not exceed 6 mA per pole for utilization categories AC-21, AC-22, AC-23, AC-23e, DC-21, DC-22 and DC-23.

Equipment of utilization categories AC-20A, AC-20B, DC-20A and DC-20B is not submitted to this test.

The total number of operating cycles shall be as declared by the manufacturer.

9.5.4 Damp heat, salt mist, vibration and shock

These special tests shall be made either at the discretion of the manufacturer or according to an agreement between the manufacturer and user (see 3.8.4 of IEC 60947-1:2020). As special tests, unless specifically called for, these additional tests are not mandatory, and it is not necessary for a switch, disconnector, switch-disconnector or fuse combination unit to satisfy any of these tests to conform to this document.

Annex Q of IEC 60947-1:2020 applies.

Product verification and operational capability after the test shall be demonstrated by compliance with the relevant requirements of 9.3.4.7.

Annex A
(normative)

Equipment for direct switching of a single motor

A.1 General

Switches, switch-disconnectors and fuse-combination units normally intended for direct switching of individual motors shall comply with the additional requirements of Annex A. These requirements are essentially the same as the appropriate subclauses of IEC 60947-4-1:2018 and equipment complying with this annex may state on the nameplate the appropriate utilization category according to Table A.1.

A.2 Rated

A.2.1 Intermittent periodic duty or intermittent duty

Subclause 5.3.4.3 of IEC 60947-1:2020 applies with the following additions.

According to the number of operating cycles, which they shall be capable of carrying out per hour, equipment is divided into the following classes:

– class 1: up to 1 operating cycle per hour;
– class 3: up to 3 operating cycles per hour;
– class 12: up to 12 operating cycles per hour;
– class 30: up to 30 operating cycles per hour;
– class 120: up to 120 operating cycles per hour.

A.2.2 Temporary duty

Subclause 5.3.4.4 of IEC 60947-1:2020 applies.

A.3 Making and breaking capacities

An equipment is defined by its making and breaking capacities, in accordance with utilization categories as specified in Table A.2 (see Clause A.4).

A.4 Utilization category

The utilization categories as given in Clause A.2 are considered standard in this annex. Any other type of utilization category shall be based on agreement between manufacturer and user but information given in the manufacturer's catalogue or tender may take the place of such an agreement.

Each utilization category is characterized by the values of the currents and voltages, expressed as multiples of the rated operational current and of the rated operational voltage, and by the power-factors or time-constants as shown in Table A.2 and other test conditions used in the definitions of the rated making and breaking capacities.

For equipment defined by their utilization category, it is therefore unnecessary to specify separately the rated making and breaking capacities as these values depend directly on the utilization category as shown in Table A.2.

The utilization categories of Table A.2 correspond in principle to the applications listed in Table A.1.

Table A.1 – Utilization categories

Utilization categories		Typical applications
AC	AC-2	Slip-ring motors: starting, plugging [a], switching off
	AC-3	Squirrel-cage motors [c]: starting, switching off motors during running, reversing [d f]
	AC-3e	Squirrel-cage motors with higher locked rotor current [e]: starting, switching off motors during running, reversing [d f]
	AC-4	Squirrel-cage motors: starting, plugging [a], inching [b]
DC	DC-3	Shunt motors: starting, plugging [a], inching [b], dynamic breaking of DC motors
	DC-5	Series-motors: starting, plugging [a], inching[b], dynamic breaking of DC motors
The switching of rotor circuits, capacitors or tungsten filament lamps shall be subject to special agreement between manufacturer and user.		

[a] Plugging is understood to mean stopping or reversing the motor rapidly by reversing motor primary connections while the motor is running.

[b] Inching (jogging) is understood to mean energizing a motor once or repeatedly for short periods to obtain small movements of the driven mechanism.

[c] Asynchronous motor of design N and H according to IEC 60034-12.

[d] Reversing is understood to mean reversing the direction of movement by reversing the motor primary connections only when the motor is not running.

[e] Asynchronous motor of design NE and HE, according to IEC 60034-12, having extended/higher locked rotor apparent power and current than design N and H respectively, to achieve a higher efficiency class according to IEC 60034-30-1.

[f] AC-3 category may be used for occasional inching (jogging) or plugging for limited time periods such as machine set-up; during such limited time periods, the number of such operations should not exceed five per minute or more than ten in a 10-min period.

Table A.2 – Rated making and breaking capacity conditions corresponding to several utilization categories

Utilization categories	Make and break conditions					
	I_c/I_e	U_r/U_e	cos ϕ	On-time s [b]	Off-time s	Number of operating cycles
AC-2	4,0	1,05	0,65	0,05	[c]	50
AC-3 [e]	8,0	1,05	[a]	0,05	[c]	50
AC-3e [e]	8,5	1,05	[a]	0,05	[c]	50
AC-4 [e]	10,0	1,05	[a]	0,05	[c]	50
			L/R ms			
DC-3	4,0	1,05	2,5	0,05	[c]	50 [f]
DC-5	4,0	1,05	15,0	0,05	[c]	50 [f]
	Make conditions					
Utilization categories	I/I_e	U/U_e	cos ϕ	On-time s [b]	Off-time s	Number of operating cycles
AC-3	10	1,05 [d]	[a]	0,05	10	50
AC-3e	12 [g]	1,05 [d]	[g]	0,05	10	50
AC-4	12	1,05 [d]	[a]	0,05	10	50

Key

I = current made. The making current is expressed in DC or AC RMS symmetrical values but it is understood that for alternating current the peak value of the asymmetrical current corresponding to the power-factor of that circuit may assume a higher value.

I_c = current made and broken, expressed in DC or AC RMS symmetrical values

I_e = rated operational current

U = applied voltage

U_r = power frequency or DC recovery voltage

U_e = rated operational voltage

cos ϕ = power-factor of test circuit

L/R = time-constant of test circuit

[a] cos ϕ = 0,45 for $I_e \leq$ 100 A, 0,35 for $I_e >$ 100 A.

[b] Time may be less than 0,05 s provided that contacts are allowed to become properly seated before re-opening.

[c] See Table A.3.

[d] For U/U_e a tolerance of ±20 % is accepted.

[e] The make conditions shall also be verified but may be combined with the make and break test if agreed by the manufacturer. The making current multiples are to be as shown for I/I_e and the breaking current as shown for I_c/I_e. The off-time is to be taken from Table A.3.

[f] 25 operating cycles with one polarity and 25 operating cycles with reverse polarity.

[g] Cos ϕ = 0,35 for $I_e \leq$ 100 A; Cos ϕ = 0,25 for $I_e >$ 100 A.

It is at the discretion of the manufacturer to choose any factor I/I_e between 12 and 13. In this case, the power factor is given by the following formulas:

$I_e \leq$ 100 A: cos $\phi = 0{,}1 \times I/I_e - 0{,}85$

$I_e >$ 100 A: cos $\phi = 0{,}1 \times I/I_e - 0{,}95$

Table A.3 – Relationship between current broken I_c and off-time for the verification of the rated making and breaking capacities

Current broken I_c A					Off-time s
		I_c	≤	100	10
100	<	I_c	≤	200	20
200	<	I_c	≤	300	30
300	<	I_c	≤	400	40
400	<	I_c	≤	600	60
600	<	I_c	≤	800	80
800	<	I_c	≤	1 000	100
1 000	<	I_c	≤	1 300	140
1 300	<	I_c	≤	1 600	180
1 600	<	I_c			240

The values of off-time may be reduced if agreed by the manufacturer.

A.5 Operational performance

Subclause 8.2.4.2 of IEC 60947-1:2020 applies with the following additions.

Equipment shall be capable of making and breaking currents without failure under the conventional conditions stated in Table A.4 for the required utilization categories and the number of operations indicated therein.

Table A.4 – Operational performance – Conditions for making and breaking corresponding to several utilization categories

Utilization categories	Make and break conditions					
	I_c/I_e	U_r/U_e	cos ϕ	On-time s [b]	Off-time s	Number of operating cycles
AC-2	2,0	1,05	0,65	0,05	[c]	6 000
AC-3	2,0	1,05	[a]	0,05	[c]	6 000
AC-3e	2,0	1,05	[a]	0,05	[c]	6 000
AC-4	6,0	1,05	[a]	0,05	[c]	6 000
			L/R ms			
DC-3	2,5	1,05	2,0	0,05	[c]	6 000 [d]
DC-5	2,5	1,05	7,5	0,05	[c]	6 000 [d]

Key

I_c = current made or broken. The making current is expressed in DC or AC RMS symmetrical values but it is understood that the actual value will be the peak value corresponding to the power-factor of the circuit.

I_e = rated operational current

U_r = power frequency or DC recovery voltage

U_e = rated operational voltage

L/R = time-constant of test circuit

[a] cos ϕ = 0,45 for I_e ≤ 100 A, 0,35 for I_e > 100 A.

[b] Time may be less than 0,05 s provided that contacts are allowed to become properly seated before re-opening.

[c] These off-times shall be not greater than the values specified in Table A.3.

[d] 3 000 operating cycles with one polarity and 3 000 operating cycles with reverse polarity.

A.6 Mechanical durability

Subclause 8.2.4.3.1 of IEC 60947-1:2020 applies with the following addition.

The preferred numbers of no-load operating cycles expressed in millions are

0,001 – 0,003 – 0,01 – 0,03 – 0,1 – 0,3 and 1.

If no mechanical endurance is stated by the manufacturer, a class of intermittent duty implies a minimum mechanical endurance corresponding to 8 000 h of operation at the highest corresponding frequency of operating cycles (see A.2.1).

A.7 Electrical durability

Subclause 8.2.4.3.2 of IEC 60947-1:2020 applies with the following addition.

The total number of on-load operating cycles shall be as declared by the manufacturer.

A.8 Verification of making and breaking capacities

See 9.3.4.4 except that the test values shall be in accordance with Table A.2 and Table A.3.

With the agreement of the manufacturer, the tests of Clause A.8 and Clause A.9 may be conducted on the same sample.

A.9 Operational performance test

See 9.3.5.2 except that the test conditions shall be in accordance with Table A.4.

With the agreement of the manufacturer, the tests of Clause A.8 and Clause A.9 may be conducted on the same sample.

A.10 Special tests

A.10.1 General

Resistance to mechanical and/or electrical wear is demonstrated by the operational performance test detailed in Clause A.9.

Where abnormal service conditions are expected (see also 8.2.4.3 of IEC 60947-1:2020), the following tests may be necessary.

A.10.2 Mechanical durability test

A.10.2.1 Condition of the equipment for tests

The equipment shall be installed as for normal service; in particular, the conductors shall be connected in the same manner as for normal use.

During the test there shall be no voltage or current in the main circuit. The equipment may be lubricated before the test if lubrication is required in normal service.

A.10.2.2 Operating conditions

The equipment shall be operated as in normal service.

A.10.2.3 Test procedure

a) The tests are carried out at the frequency of operations corresponding to the class of intermittent duty. However, if the manufacturer considers that the equipment can satisfy the required conditions when using a higher frequency of operations, he may do so.

b) The number of operating cycles to be carried out shall be not less than the number of no-load operating cycles stated by the manufacturer.

c) After each tenth of the total number of operations has been carried out, it is permissible before carrying on with the test
   - to clean the whole equipment without dismantling;
   - to lubricate parts for which lubrication is required by the manufacturer for normal service;
   - to adjust the travel and the pressure of the contacts if the design of the equipment enables this to be done.

d) This maintenance work shall not include any replacement of parts.

A.10.2.4 Results to be obtained

Following the tests of mechanical durability, the equipment shall still be capable of complying with the normal operating conditions at room temperature. There shall be no loosening of the parts used for connecting the conductors.

A.10.3 Electrical durability test

With respect to its resistance to electrical wear, an equipment is, by convention, characterized by the number of on-load operating cycles, corresponding to the different utilization categories given in Table A.5 which can be made without repair or replacement.

In all cases, the speed and number of operating cycles shall be chosen by the manufacturer.

The tests shall be taken as valid if the values recorded in the test report differ from the values specified only within the tolerances stated in 9.3.2.2.2 of IEC 60947-1:2020.

Tests shall be carried out with the equipment under the appropriate conditions of A.10.2.1 and A.10.2.2 using the test procedure, where applicable, of A.10.2.3, except that replacement of contacts is not permitted.

After the test, the equipment shall fulfil the normal operating conditions specified in 9.3.4.3 and withstand a dielectric test voltage of twice the rated operational voltage U_e, but not less than 1 000 V, applied only as specified in 9.3.3.4.1, item 4) b), of IEC 60947-1:2020.

Table A.5 – Verification of the number of on-load operating cycles – Conditions for making and breaking corresponding to several utilization categories

Utilization categories	Values of the rated operational current	Make			Break		
		I/I_e	U/U_e	cos ϕ [a]	I_c/I_e	U_r/U_e	cos ϕ [a]
AC-2	All values	2,5	1	0,65	2,5	1	0,65
AC-3	$I_e \leq 17$ A	6	1	0,65	1	0,17	0,65
	$I_e > 17$ A	6	1	0,35	1	0,17	0,35
AC-3e	$I_e \leq 17$ A	6	1	0,65	1	0,17	0,65
	$I_e > 17$ A	6	1	0,35	1	0,17	0,35
AC-4	$I_e \leq 17$ A	6	1	0,65	6	1	0,65
	$I_e > 17$ A	6	1	0,35	6	1	0,35
		I/I_e	U/U_e	L/R [b] ms	I_c/I_e	U_r/U_e	L/R [b] ms
DC-3	All values	2,5	1	2	2,5	1	2
DC-5	All values	2,5	1	7,5	2,5	1	7,5

Key

I_e = rated operational current

U_e = rated operational voltage

I = current made. In alternating current the conditions for making are expressed in RMS symmetrical values but it is understood that the peak value of asymmetrical current, corresponding the power-factor of the circuit, may assume a higher value

U = applied voltage

U_r = power frequency and DC recovery voltage

I_c = current broken

L/R = time-constant of test circuit

[a] Tolerance for cos ϕ: ±0,05.

[b] Tolerance for L/R: ±15 %.

A.11 Critical load current performance for DC equipment

The main circuits of equipment shall be capable of making and breaking its critical load current according to 9.3.9 and verified by test sequence VI (see 9.3.9).

Annex B
(informative)

Items subject to agreement between manufacturer and user

NOTE For the purpose of Annex B:

– "agreement" is used in a very wide sense;

– "user" includes testing stations.

Annex J of IEC 60947-1:2020 applies with regard to clauses and subclauses of this document and with the following additions.

Clause or subclause numbers of this document	Items
5.4	Switching of capacitors or of tungsten filament lamps
8.1.7.2 NOTE	Locking in the closed position for particular applications
8.2.4.2 and Table 5	Increase of the operating rate for the verification of the operational performance
9.3.4.4.1	Time interval greater than 30 s ± 10 s between close-open cycles for making and breaking capacity test of equipment of I_{th} > 400 A
	For categories AC-23A and AC-23B testing of making and breaking capacities by make cycles at 10 I_e followed by the same number of make-break cycles at 8 I_e
9.3.4.4.3	Verification of making and breaking capacities for utilization categories DC-22 and DC-23: replacement of the load of the test circuit by a motor
9.3.6.3.3	AC test circuit calibration for the short-circuit making capacity test in the case of DC equipment
Clause A.4	Utilization categories other than those listed in Table A.2
Table A.1	Switching of rotor circuits, capacitors or tungsten filament lamps
Clause A.8	Verification of making and breaking capacities
Clause A.9	Operational performance test

Annex C
(normative)

Single pole operated three-pole switches

C.1 General

All requirements of this document apply except where modified by the following.

The test requirements according to this document for verification of making and breaking capacities, operational performance and conditional short-circuit withstand, apply to devices with poles operated simultaneously. They are therefore not suitable for three-phase switches operated pole by pole.

Important characteristics of three-phase switches operated pole by pole and relevant for the above-mentioned tests are as follows:

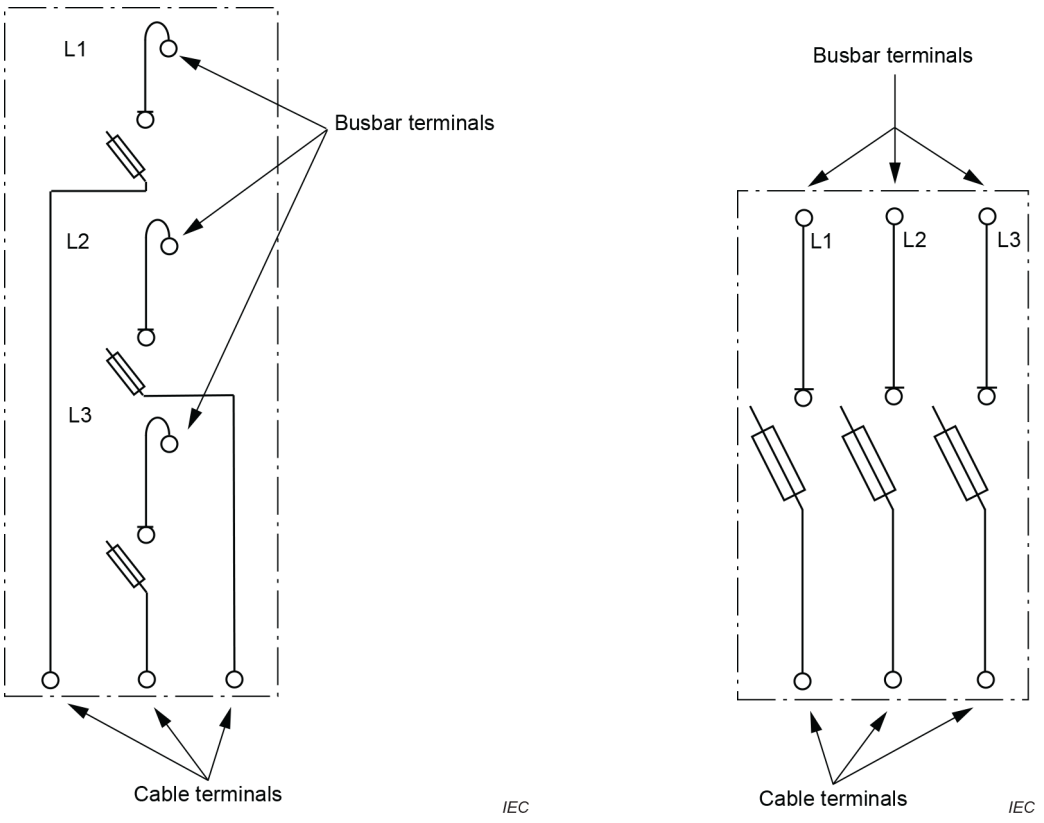
– the three poles are operated individually and are positioned adjacent to each other.

  The three phases can typically be situated beside each other (horizontal version, see Figure C.1 b)) or below each other (vertical version, see Figure C.1 a)).

– the sequence of operation of the poles is at the discretion of a skilled operator.

– the design of the individual poles shall be fundamentally the same.

The position of the device under test shall be defined by the manufacturer and stated in the test report.



a) Vertical arrangement **b) Horizontal arrangement**

Figure C.1 – Typical arrangements

C.2 Tests

When testing single pole operated three-pole switches, the relevant test sequences of Table 10 shall be applied with the following identified tests, modified in accordance with Clause C.3:

– 9.3.4.4 – Making and breaking capacities of test sequence I;

– 9.3.5.2 – Operational performance of test sequence II;

– 9.3.7.3.1 b) – Making of test sequence IV.

C.3 Test set-up and sequence

C.3.1 Making and breaking capacities (9.3.4.3) and operational performance (9.3.5.2)

Test 1: With L1 and L2 closed, L3 is subjected to the required make-break operation cycle.

Test 2: With L2 closed and L3 open, L1 is subjected to the required make-break operation cycle.

All tests shall be performed in a three-phase test circuit according to Figure 5 of IEC 60947-1:2020.

C.3.2 Fuse protected short-circuit test (9.3.7.3)

For the making test of the fuse-switch, the following test shall be applied.

With L1 open and L2 closed, L3 is subjected to the required make operation cycle. The test shall be performed in a three-phase test circuit according to Figure 11 of IEC 60947-1:2020.

C.4 Condition of equipment after tests

The equipment shall comply with the relevant clauses of 9.3.4.4.5, 9.3.5.2.6 and 9.3.6.3.6.

C.5 Instructions for use

The manufacturer shall include within the product literature the following statement.

These devices are intended for power distribution systems where switching and/or isolation of an individual phase may be necessary and shall not be used for the switching of the primary circuit of three-phase equipment.

Annex D
(normative)

Switches, disconnectors, switch-disconnectors and fuse-combination units for use in photovoltaic (PV) DC applications

D.1 General

D.1.1 Background

As part of the answer to the challenge of sustainable development, the number of photovoltaic (PV) installations is increasing. This latest development in photovoltaic (PV) technology is challenging the conventional approach to energy sources and power distribution systems, including their operating conditions and environment.

PV applications have particular characteristics and require equipment with specific performance. These performance requirements are identified for IEC 60947-3 products in this annex.

NOTE The abbreviated term "PV" (photovoltaic) is used in this annex.

The provisions of this document are applicable to equipment specified in this annex, where specifically identified. Clauses, subclauses, tables, figures and annexes of this document thus applicable are identified by their particular reference, for example as "5.3.5.1", "Table 2" or "Annex A".

D.1.2 Object

This annex applies to DC switches, disconnectors, switch-disconnectors and fuse-combination units, rated up to 1 500 V DC, intended for use in photovoltaic (PV) systems, and hereafter referred to as "PV switches, PV disconnectors, PV switch-disconnectors and PV fuse-combination units".

Switches, disconnectors, switch-disconnectors and fuse-combination units used in PV systems are subject to electrical, environmental and operational conditions that differ from the general conditions taken into account in the main body of this document. The requirements have thus been adapted to reflect these conditions of use.

The object of this annex is to state:

– the requirements for PV switches, PV disconnectors, PV switch-disconnectors and PV fuse-combination units to be used on the DC side of PV applications;
– the tests to verify that the product performance is consistent with the PV applications and the expected life in PV environmental conditions.

D.2 Normative references

Clause 2 applies with the following addition:

IEC 60068-2-14:2009*, Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

D.3 Terms and definitions

Clause 3 applies.

D.4 Classification

Clause 4 applies with the following changes:

D.4.1 According to the utilization category

For PV applications, the utilization categories given in existing Table 2 are replaced by DC-PV0, DC-PV1 or DC-PV2 (see Table D.1).

D.5 Characteristics

Clause 5 applies with the following changes:

D.5.3.6.1 Ability to withstand motor switching overload currents

Subclause 5.3.6.1 is not applicable.

D.5.3.6.2 Rated making capacity

Replace, in the second paragraph of 5.3.6.2, "Table 4" *by* "Table D.6".

D.5.3.6.3 Rated breaking capacity

Replace, in the second paragraph of 5.3.6.3, "Table 4" *by* "Table D.6".

D.5.3.7.1 Rated short-time withstand current (I_{cw})

Subclause 5.3.7.1 applies as follows:

Equipment with utilization category:

a) DC-PV1: rated short-time withstand current is not applicable;
b) DC-PV0 and DC-PV2: in accordance with 5.3.7.1.

D.5.4 Utilization category

Replace the existing text of 5.4 by the following:

The utilization categories define the intended application and are given in Table D.1.

Each utilization category is characterized by the values of the currents and voltages, expressed as multiples of the rated operational current and rated operational voltage, as well as the time constant of the circuit. The conditions for making and breaking given in Table D.6 correspond to the application listed in Table D.1.

Table D.1 – Utilization categories

Utilization category	Typical applications
DC-PV0	Opening and closing a PV circuit to provide disconnection when no current is flowing.
DC-PV1	Connecting and disconnecting single PV string(s) where reverse currents and significant overcurrent cannot occur.
DC-PV2	Connecting and disconnecting PV circuits where significant overcurrents may prevail and where current flow can be in both directions; for example, where several strings are connected in parallel and to the same inverter, or one or more strings with a battery.

D.6 Product information

Clause 6 applies.

D.7 Normal service, mounting and transport conditions

Clause 7 applies, with the following changes:

Annex D covers the use of PV switches, PV disconnectors, PV switch-disconnectors and PV fuse-combination units for use in the alternative service arrangements detailed in Table D.2.

Table D.2 – Service arrangements

Unenclosed	Unenclosed PV switches, PV disconnectors, PV switch-disconnectors or PV fuse-combination units that have a conventional free air thermal current rating and that are suitable for installation within a cabinet or enclosure, which may be suitable for indoor or outdoor use.
Enclosed	Enclosed PV switches, PV disconnectors, PV switch-disconnectors or PV fuse-combination units that have a conventional enclosed thermal current rating and that are suitable for installation in indoor or outdoor locations.

D.7.1.1 Ambient air temperature

Replace 7.1.1 of IEC 60947-1:2020 by the following:

The ambient air temperature does not exceed the maximum and minimum values given in Table D.3. Daily average ambient air temperature over a period of 24 h does not exceed 35 °C.

Table D.3 – Environmental conditions

Environmental class	Maximum ambient air temperature without de-rating	Minimum ambient air temperature	Comment
Unenclosed	+40 °C	–5 °C	Guidance on de-rating for higher ambient air temperature up to 70 °C may be provided. In addition, guidance on operation at temperature lower than −5 °C may also be given.
Enclosed – Indoor	+40 °C	–5 °C	Normal indoor service conditions in accordance with Clause 6.
Enclosed – Outdoor	+40 °C (without solar effects)	–25 °C	Rating applies when the enclosed equipment is subjected to solar radiation of 1,2 kW/m^2 and the maximum ambient air temperature. Guidance may be provided on de-rating of enclosed equipment to be installed in locations with a higher maximum ambient air temperature and/or lower minimum ambient air temperature

Ambient air temperature is that existing in the vicinity of the equipment if supplied without an enclosure, or in the vicinity of the enclosure if supplied with an enclosure.

D.8 Constructional and performance requirements

Clause 8 applies with the following addition:

Enclosures shall comply with IEC 62208.

D.8.1.4 Clearances and creepage distances

Subclause 8.1.4 of IEC 60947-1:2020 applies with the following modification:

The minimum rated impulse voltage shall be in accordance with Table D.4.

D.8.1.12 Degrees of protection of enclosed equipment

Subclause 8.1.12 of IEC 60947-1:2020 applies with the following addition:

The degree of protection provided by the enclosure against contact with live parts, ingress of solid foreign bodies and water as indicated by the IP code according to Annex C of IEC 60947-1:2020, shall be declared by the manufacturer. For indoor enclosed and outdoor enclosed equipment this shall not be less than IP2X and IP33, respectively.

D.8.2.3 Dielectric properties

Subclause 8.2.3 of IEC 60947-1:2020 applies with the following changes:

PV switches, PV disconnectors, PV switch-disconnectors and PV fuse-combination units shall have a rated impulse withstand voltage as given in Table D.4.

NOTE In general, for PV circuits, overvoltage category II is assumed, and the impulse withstand voltage ratings for the PV circuit are assigned based on the PV system voltage, with a minimum impulse voltage of 2,5 kV.

Table D.4 – Rated impulse withstand levels for PV switches, PV disconnectors, PV switch-disconnectors or PV fuse-combination units

Maximum value of rated operational voltage DC V	Impulse withstand voltage used in DC PV equipment kV
300	2,5
600	4,0
1 000	6,0
1 500	8,0
Interpolation is not permitted in main circuits. NOTE 1 These values are based on requirements in IEC 60364-7-712 for overvoltage category II as defined in IEC 60664-1 and in Annex D of IEC TR 60664-2-1:2011. NOTE 2 The application of surge arrestors is the responsibility of the assembly/installation designer.	

D.8.2.4.1 Making and breaking capacities

Replace 8.2.4.1 by the following:

PV switches, PV switch-disconnectors and PV fuse-combination units shall be capable of interrupting any current up to their rated making and breaking capacities. Compliance with these requirements is checked by the tests of 9.3.4.4 as modified by D.9.3.4.4.1.

The rated making and breaking capacities are stated by reference to the rated operational voltage, rated operational current and to the PV utilization category according to Table D.5.

Test conditions are as specified in D.9.3.5.2.1.

For PV switches, PV switch-disconnectors and PV fuse-combination units with a utilization category DC-PV1, the test supply shall be connected in accordance with the terminal markings (generator, load, "+" and "−"). Equipment with a utilization category DC-PV2 shall have one sequence of tests carried out on a sample with the test supply and load connected to the main poles, as convenient. Unless the manufacturer can demonstrate the contact system and arc control arrangement is symmetrical in respect of current flow in each pole, the sequence shall then be repeated on a new sample with the supply and load terminals interchanged.

Table D.5 – Verification of rated making and breaking capacities (see 9.3.4.4) – Conditions for making and breaking corresponding to the DC-PV category

Utilization categories	Making and breaking			Number of operating cycles[a]
	I/I_e and I_c/I_e	U/U_e	L/R ms	
DC-PV0	–	–	–	
DC-PV1	1,5	1,05	1	5
DC-PV2	4	1,05	1	5

[a] One switching operation without current between each making and breaking operation is allowed, providing it does not alter the time interval between the required operations as defined in 9.3.4.4.1.

D.8.2.4.2 Operational performance

Replace 8.2.4.2 by the following:

D.8.2.4.2.1 Operational performance at a normal ambient air temperature

Tests concerning the verification of the operational performance of equipment are intended to verify that the equipment is capable of making and breaking without failure any current up to the rated current, including the critical load current. Compliance with the operational performance requirements is checked by the tests of 9.3.5 as modified by D.9.3.5.2.1.

NOTE Requirements for operation at the critical load current is dealt with separately in D.8.2.8.

The number of operating cycles and the test circuit parameters for the operational performance tests for the various utilization categories are given in Table D.6 and Table D.7.

Test conditions are as specified in D.9.3.5.2.1.

For PV switches, PV disconnectors, PV switch-disconnectors and PV fuse-combination units with a utilization category DC-PV1, the test supply shall be connected in accordance with the terminal markings (generator, load, "+" and "−"). Equipment with a utilization category DC-PV2 shall have one sequence of tests carried out on a sample with the test supply and load connected to the main poles, as convenient. Unless the manufacturer can demonstrate the contact system and arc control arrangement is symmetrical in respect of current flow in each pole, the sequence shall then be repeated on a new sample with the supply and load terminals interchanged.

Table D.6 – Number of operating cycles

Rated operational current I_e A	Number of operating cycles per hour [b]	Number of operating cycles [a]		
		Without current	With current [c]	Total [d]
$I_e \leq 100$	120	9 700	300	10 000
$100 < I_e \leq 315$	120	7 800	200	8 000
$315 < I_e \leq 630$	60	4 800	200	5 000
$630 < I_e \leq 2\,500$	20	2 900	100	3 000
$2\,500 < I_e$	10	1 900	100	2 000

[a] At the discretion of the manufacturer, the number of operating cycles with current may be increased whilst the total number of operating cycles remains unchanged.

[b] Column 2 gives the minimum operating rate. This operating rate may be increased with the consent of the manufacturer, in which case the rate used shall be stated in the test report.

[c] During each operating cycle, the PV switches, PV switch-disconnectors and PV fuse-combination units shall remain closed for a sufficient time to ensure that the full current is established, but not exceeding 2 s.

[d] PV disconnectors shall comply with the number of operating cycles in the “Total” column without current.

Table D.7 – Test circuit parameters for Table D.6

Utilization categories	Making and breaking		
	I/I_e and I_c/I_e	U/U_e	L/R ms
DC-PV1	1	1	1
DC-PV2	1	1	1

Key

I = making current

I_c = breaking current

I_e = rated operational current

U = applied voltage

U_e = rated operational voltage

L/R = time-constant of test circuit

D.8.2.4.2.2 Operational performance at a low ambient air temperature

The following test shall be carried out on equipment intended to be used in outdoor enclosures to verify operation at an ambient air temperature of −25 °C.

The test can be carried out on an enclosed or unenclosed device, however, all mechanical couplings and the handle shall be included in the test. In addition, if the enclosure is made of plastic, it shall be included in the test.

The test shall be carried out following conditioning at a temperature not higher than −25 °C for a period of at least 24 h prior to the test being carried out.

Repeat of operational performance sequence test detailed in D.8.2.4.2.1 on a sample in new and clean condition, with the following changes:

– all operating cycles shall be carried out without current;

– number of operating cycles shall be 100 at the frequency given in Table D.6;

– operating cycles shall be carried out with the device under test located in an ambient air temperature between −25°C and −30°C.

D.8.2.4.4 Electrical durability

Subclause 8.2.4.3.2 of IEC 60947-1:2020 applies. Test conditions are specified in D.9.5.2.

D.8.2.8 Critical load current performance

The main circuits of an equipment shall be capable of making and breaking its critical load current according to 9.3.9 and verified by test sequence VI as modified by D.9.3.9.

D.9 Tests

Clause 9 applies with the following modifications:

D.9.3.2 Test sequences

Subclause 9.3.2 applies with the following changes:

Replace Table 10 with the following Table D.8:

Table D.8 – Overall scheme of test sequences

Sequences	Test
General performance characteristics (see 9.3.4 as modified by D.9.3.4.4.1)	Temperature-rise [e, f] Dielectric properties [e] Making and breaking capacities [a] Dielectric verification [a] Leakage current [b] Temperature-rise verification Strength of actuator mechanism
Operational performance capability – equipment types (see 9.3.5 as modified by D.9.3.5.2.1 and D.9.3.5.2.2)	Operational performance Dielectric verification Leakage current [b] Temperature-rise verification
Operational performance capability – enclosed outdoor equipment (see 9.3.5 as modified by D.8.2.4.2.2 and D.9.3.5.2.1)	Operational performance Dielectric verification Leakage current [b] Temperature-rise verification
Short-circuit performance capability [c] (see 9.3.6 as modified by D.9.3.6.2.2)	Short-time withstand current Short-circuit making capacity [a] Dielectric verification Leakage current [b] Temperature-rise verification
Conditional short-circuit current [c] (see 9.3.7)	Fuse protected short-circuit withstand Fuse protected short-circuit making [a] Dielectric verification Leakage current [b] Temperature-rise verification
Overload performance capability [d] (see 9.3.8 as modified by D.9.3.8.2)	Overload test Dielectric verification Leakage current [b] Temperature-rise verification
Critical load current (DC) performance (see 9.3.9 as modified by D.9.3.9)	Critical load current test Dielectric verification Leakage current [b] Temperature-rise verification
Thermal cycling (see D.9.3.10)	Thermal cycling test Temperature-rise verification Mechanical operation Dielectric verification
Climatic (see D.9.3.11)	Climatic test Temperature-rise verification
Temperature-rise verification with solar effects – Enclosed outdoor units only (see D.9.3.12)	Temperature-rise verification with simulated solar effects
Verification of resistance of insulating materials to abnormal heat and fire (see D.9.3.13)	Glow wire test
Degree of protection – enclosed units only (see D.9.3.14)	IP test
Clearance and creepage distances (see D.9.3.15)	Measurement of creepage and clearance distances
EMC (see D.9.4)	EMC test

[a] Not applicable to DC-PV0 equipment. See 5.3.6.2 and 5.3.6.3.

[b] Only required for equipment suitable for isolation of rated voltage greater than 50 V.

[c] Either test sequence III or test sequence IV to be made according to the ratings stated by the manufacturer.

[d] Not required for switches, disconnectors and switch-disconnectors.

[e] May be conducted outside of the sequence, see 9.3.2.

[f] Applies to 9.3.3.4 only.

D.9.3.3 General test conditions

D.9.3.3.1 General requirements

Subclause 9.3.3.1 applies with the following addition:

For all tests, the connection of poles of the PV switches, PV disconnectors, PV switch-disconnectors and PV fuse-combination units shall be in accordance with the manufacturer's installation instructions.

D.9.3.4.4.1 Test values and conditions

Subclause 9.3.4.4.1 applies with the following modifications:

Replace all references to Table 4 by Table D.5.

Subclause 9.3.4.4.1, sixth paragraph is not applicable.

D.9.3.5.2.1 Test values and conditions

Subclause 9.3.5.2.1 applies with the following modifications:

Replace all references to existing Table 5 and Table 6 by Table D.6 and Table D.7 respectively.

D.9.3.5.2.2 Test circuit

Replace 9.3.5.2.2 by the following:

Subclause 9.3.4.1.2 of IEC 60947-1:2020 applies.

The time constant of the test circuit shall be 1 ms.

At the discretion of the manufacturer, a higher value of time constant may be used. In this case, it should be stated in the test report.

D.9.3.6.2.2 Test circuit

Replace 9.3.6.2.2 by the following:

Subclause D.9.3.5.2.2 applies.

D.9.3.8.2 Overload test

Subclause 9.3.8.2 applies with the following changes:

Replace the existing first paragraph with the following:

The equipment shall first be temperature-conditioned at room temperature. The test current is 1,45 × I_{the} or 1,45 × I_{th} for a period of 1 h, or until one or more of the gPV fuse-links operate.

If the time is less than the specified period, the time shall be recorded in the test report.

D.9.3.9 Critical load current performance of equipment with a DC rating

Subclause 9.3.9. applies with the following modifications:

Replace all references to existing Table 18 and Table 19 by Table D.9 and Table D.10 respectively.

Table D.9 – Number of operating cycles corresponding to the critical load current

Category	Rating of the product A	Number of operating cycles per hour	Number of operating cycles at I_{crit}
DC-PV1 and DC-PV2	$I_e \leq 315$	120	100
	$315 < I_e \leq 630$	60	100
	$630 < I_e \leq 2\,500$	20	100
	$I_e > 2\,500$	10	100

Table D.10 – Test circuit parameters for Table D.9

Utilization category	Rated operational current	Making and breaking		
		I	U/U_e	L/R ms
DC-PV1 and DC-PV2	All values	I_{crit}	1	1

D.9.3.10 Thermal cycling test

PV switches, PV disconnectors, PV switch-disconnectors and PV fuse-combination units, including the enclosure where applicable, shall be subjected to temperature cycling test according to IEC 60068-2-14, test Nb, comprising 50 cycles, each cycle consisting of 1 h at −40 °C followed by 1 h at +85 °C. The test should be performed when the product is in closed position. The temperature change rate shall be 1 K/min. At the conclusion of the 50 cycles, the equipment shall be returned to room temperature of (25 ± 5) °C for a minimum of 3 h.

The equipment shall then be subjected to

a) visual inspection to confirm that there is no distortion or damage to parts that will affect normal operation and protection;

b) one open and close operation to confirm normal mechanical operation;

c) temperature-rise test of 9.3.4.7;

d) dielectric test in accordance with 9.3.4.5.

The number of samples shall be in accordance with the requirements of Table 11 for test sequence I.

D.9.3.11 Climatic test

PV switches, PV disconnectors, PV switch-disconnectors and PV fuse-combination units shall be subjected to the climatic tests of IEC 60947-1:2020, Annex Q, category B: environment subject to temperature and humidity, except that the dry heat test and the low temperature test are not required, as they are deemed to be covered by the thermal cycling test in D.9.3.10.

Product verification and operational capability after the test shall be demonstrated by compliance with relevant requirements of 9.3.4.7.

The number of samples shall be in accordance with the requirements of Table 11 for test sequence I. At the discretion of the manufacturer, this test may be combined with the thermal cycling test and made on the same samples.

D.9.3.12 Temperature-rise verification with solar effects – Outdoor units only

These tests only apply to enclosed units. The test shall be carried out in accordance with 9.3.4.2 plus the following additional solar effects.

The most onerous solar effects on the assembly are assumed to be mid-morning or mid-afternoon when the top, back or front and one adjacent side of the unit is subject to solar radiation. At this time the maximum solar radiation is reduced by approximately 10 %.

For the duration of the temperature-rise test, radiant heat lamps shall be used to simulate the effects of solar radiation on the top, front or back and one adjacent side of the test sample. These shall be arranged such that the average solar radiation received by the sample under test, perpendicular to the surface being considered is

top $[0,9 \times 1,2/\sqrt{2}] = 0,76\ kW/m^2$;

front or back $[0,9 \times 1,2/(\sqrt{2} \times \sqrt{2})] = 0,54\ kW/m^2$;

side $[0,9 \times 1,2/(\sqrt{2} \times \sqrt{2})] = 0,54\ kW/m^2$.

A pyranometer shall be used to measure the simulated level of solar radiation.

The ambient air temperature sensing means shall be so positioned and/or sufficiently distant from the radiant heat lamps that they are not affected by the radiation.

The average level of radiation on each of the exposed surface shall be recorded in the test report.

At the conclusion of the test, the temperature-rise shall not exceed 80 K on the terminals for external connections, assuming a maximum shade ambient air temperature of 40 °C. No other value is specified but no damage shall be caused to adjacent parts of insulating materials.

Operators should note that the temperatures of external parts that are exposed to solar radiation may be high and precautions should be taken if they need to be touched.

D.9.3.13 Verification of resistance of insulating materials to abnormal heat and fire

Insulating materials shall meet glow wire test requirements in accordance with 9.2.2.1 of IEC 60947-1:2020.

D.9.3.14 Degree of protection – Enclosed equipment

Ingress protection (IP) tests shall be carried out on enclosed equipment in accordance with Annex C of IEC 60947-1:2020 to confirm the degree of protection declared by the manufacturer has been attained.

D.9.3.15 Clearance and creepage distances

Clearance and creepage distances shall be measured to confirm compliance with D.8.1.4 (see Annex G of IEC 60947-1:2020 for guidance on measurement of creepage and clearances distances).

D.9.4 Electromagnetic compatibility tests

Electromagnetic compatibility shall be verified in accordance with 9.4.

D.9.5.2 Electrical durability

Replace 9.5.3 by the following:

The electrical durability test (see D.8.2.4.1 and 9.1.5), where required, is made in accordance with the appropriate requirements of 9.3.5.2 as modified by D.9.3.5.2.1 and D.9.3.5.2.2, except that for equipment suitable for isolation, the maximum value of leakage current shall not exceed 2 mA per pole for utilization categories DC-PV1 and DC-PV2.

The total number of operating cycles shall be declared by the manufacturer.

Annex E
(normative)

Additional requirements for LV switchgear intended for connection of aluminium conductors

E.1 Object

The purpose of Annex E is to address the needs of connecting aluminium conductors, as an alternative to copper, by specifying appropriate tests and other requirements while maintaining safety and performance.

This annex specifies the requirements for use of solid and stranded aluminium conductors and aluminium busbars with low voltage switchgear within the scope of this document, as follows:

1) Aluminium test conductors that are equivalent to, and can be used as an alternative to, the copper conductors given in Table 9 of IEC 60947-1:2020, Table 10 of IEC 60947-1:2020 and Table 11 of IEC 60947-1:2020 for terminals as depicted in Figures D.2, D.3, D.4, D.5, D.6 (including busbars) and D.7 of IEC 60947-1:2020 or similar clamping units.
2) Method for verifying the means of connecting aluminium conductors, as used in normal service for terminals as depicted in Figures D.2, D.3, D.4, D.5 and D.7 of IEC 60947-1:2020 or similar clamping units. Testing of lug terminals depicted in Figure D.6 of IEC 60947-1:2020 is specified in IEC 61238-1-1.

Terminals covered by this annex may be an integral part of the switchgear or may be provided as an accessory.

NOTE The term “terminal” used in this annex is equivalent to the term “clamping unit” used in IEC 60947-1.

Screwless terminals as depicted in Figure D.8 of IEC 60947-1:2020 and connection of flexible aluminium conductors are not covered by this annex. Terminating aluminium and copper conductors in one clamping unit at the same time is not covered by this annex.

E.2 Normative references

Clause 2 applies with the following addition:

IEC 61238-1-1, *Compression and mechanical connectors for power cables – Part 1-1: Test methods and requirements for compression and mechanical connectors for power cables for rated voltages up to 1 kV (U_m = 1,2 kV) tested on non-insulated conductors*

E.3 Terms, definitions and index of terms

Clause 3 applies with the following additions:

E.3.1
reference conductor
continuous length of the same type and size conductor as that used in the terminal unit under test and connected in the same series circuit to enable the reference temperature and, if required, reference resistance to be determined

E.3.2
equalizer
arrangement used in the test loop to ensure an equipotential point and a uniform current density in a stranded conductor, without adversely affecting the temperature of the conductor(s)

E.3.3
stability factor
S_f
measure of temperature stability of a terminal unit during the current cycling test

Note 1 to entry: Definitions for different types of terminals can be found in Annex D of IEC 60947-1:2020.

E.4 Classification

Clause 4 applies with the following additions:

According to the conductor connection:

– for use with copper only; or
– for use with either copper or aluminium; or
– for use with aluminium only.

E.5 Characteristics

Clause 5 applies.

E.6 Product information

E.6.1 Nature of information

Subclause 6.1 applies.

E.6.2 Marking

Subclause 6.2 applies with the following addition:

If the rated current of the terminals is lower than the rated current of the switchgear, it shall be marked on the switchgear or the switchgear terminals, or in the manufacturer's literature, as appropriate.

The suitability of the terminal for use with aluminium conductors only (Al) or copper and aluminium conductors (Al/Cu) shall be marked on the switchgear or the switchgear terminals, or in the manufacturer’s literature, as appropriate. When the marking is on the switchgear or terminals the abbreviations "AL" and "AL/CU" may be used.

E.6.3 Instructions for installation, operation and maintenance, decommissioning and dismantling

Subclause 6.3 applies with the following addition:

Manufacturer’s literature may include recommended installation practices such as:

– after removal of the conductor insulation and prior to termination, the aluminium conductor shall be cleaned by wire-brushing the aluminium followed by application of an anti-oxidant compound to limit oxidization of the aluminium;
– treatment of the busbar at the termination points, by wire-brushing the aluminium followed by the application of an anti-oxidant compound or by use of an electrically conductive coating such as tin;
– use of specific hardware for termination.

E.7 Normal service, mounting and transport conditions

Clause 7 applies.

E.8 Constructional and performance requirements

Clause 8 applies with the following additions:

Clamping units intended for use with aluminium conductors shall be treated with an electrically conductive coating such as tin, or alternative means that will inhibit corrosion due to the difference in electrochemical series.

The manufacturer shall specify whether the terminals are suitable for stranded, solid or both types of conductors. Performance tests shall be carried out with all conductor types specified by the manufacturer.

Aluminium conductor sizes for different currents given in Table E.7 and Table E.8 correspond to copper conductor sizes given in Table 9 of IEC 60947-1:2020, Table 10 of IEC 60947-1:2020 and Table 11 of IEC 60947-1:2020.

NOTE The conductor sizes have been derived from IEC 60898-1, UL 486E and BIS IS 13947-1.

E.9 Tests

E.9.1 General

The tests shall be performed with aluminium conductors having a cross-section corresponding to the lower of either the rated current of the device or the rated current of the terminals, as given in Table E.7.

The aluminium conductor to be used shall be single core (stranded or solid), with black insulation for all the tests applicable in E.9.2, E.9.3 and E.9.4. Cables 10 mm^2 and larger shall have electrical and mechanical properties complying with IEC 60228.

Class A aluminium alloy grade 1350, as referred to in IEC 61545, shall be used for testing purposes.

NOTE 1 Grade 1350 aluminium is generally considered to be the worst case and its use for testing is consistent with UL 486E.

NOTE 2 Requirements for terminals acceptable for use with sector shaped conductors are under consideration.

The following tests shall be carried out on either the product or the terminal specimen to be used in the final product as specified in Table E.1. Each specimen comprises a pair of terminals and conductor part.

Table E.1 – List of tests for terminal connections [a] with aluminium cables

Test		Subclause	Tested on	Number of units
Current cycling test		E.9.2	Terminal specimen	4 specimens
Mechanical properties of terminals	Flexion test	E.9.3.1	Switchgear	As per 9.2.5.3 of IEC 60947-1:2020
	Pull-out test	E.9.3.2		As per 9.2.5.4 of IEC 60947-1:2020
Insertion test		E.9.4	Switchgear	As per 9.2.5.5 of IEC 60947-1:2020

[a] Type of connection limited to clamping unit types of Figures D.2, D.3, D.4, D.5 and D.7 as per Annex D of IEC 60947-1:2020.

E.9.2 Current cycling test

E.9.2.1 General

The intent of this test is to verify the stability of the terminal by comparing the temperature performance with that of the reference conductor under current cycling conditions. This test is carried out on terminals alone, not on the switchgear.

E.9.2.2 Preparation

The test shall be performed on four specimens, each one consisting of a pair of terminals, assembled in a manner which represents the use of the terminals in the switchgear. The terminals which have been removed from the product shall be attached to conducting parts of the same cross-section, shape, metal and finish as those on which they are mounted on the product. The conducting part shall not exceed:

– three times the length of the terminal;

– the width of the terminal;

as shown in Figure E.2 below. The terminals shall be fixed to the conductor part(s) in the same manner (position, torque, etc.) as on the product.

To avoid excessive oxidation of the conductor and ensure proper connection, a sufficient length of insulation shall be removed immediately prior (without any intentional delay) to installation.

The wire shall be positioned so that 6 mm to 13 mm of the bare conductor is exposed between the wire-entry face of the terminal and the beginning of the insulation.

There shall be no mechanical removal or chemical treatment of any oxide on the surface of the conductor entering the terminal, unless it is explicitly required by the manufacturer’s instructions, in which case it shall be stated in the test report.

E.9.2.3 Test arrangement

The general arrangement of the samples shall be as shown in Figure E.1, noting that either welded, lug, brazed, soldered or clamped connections to the equalizers may be used.

Dimensions in millimeters

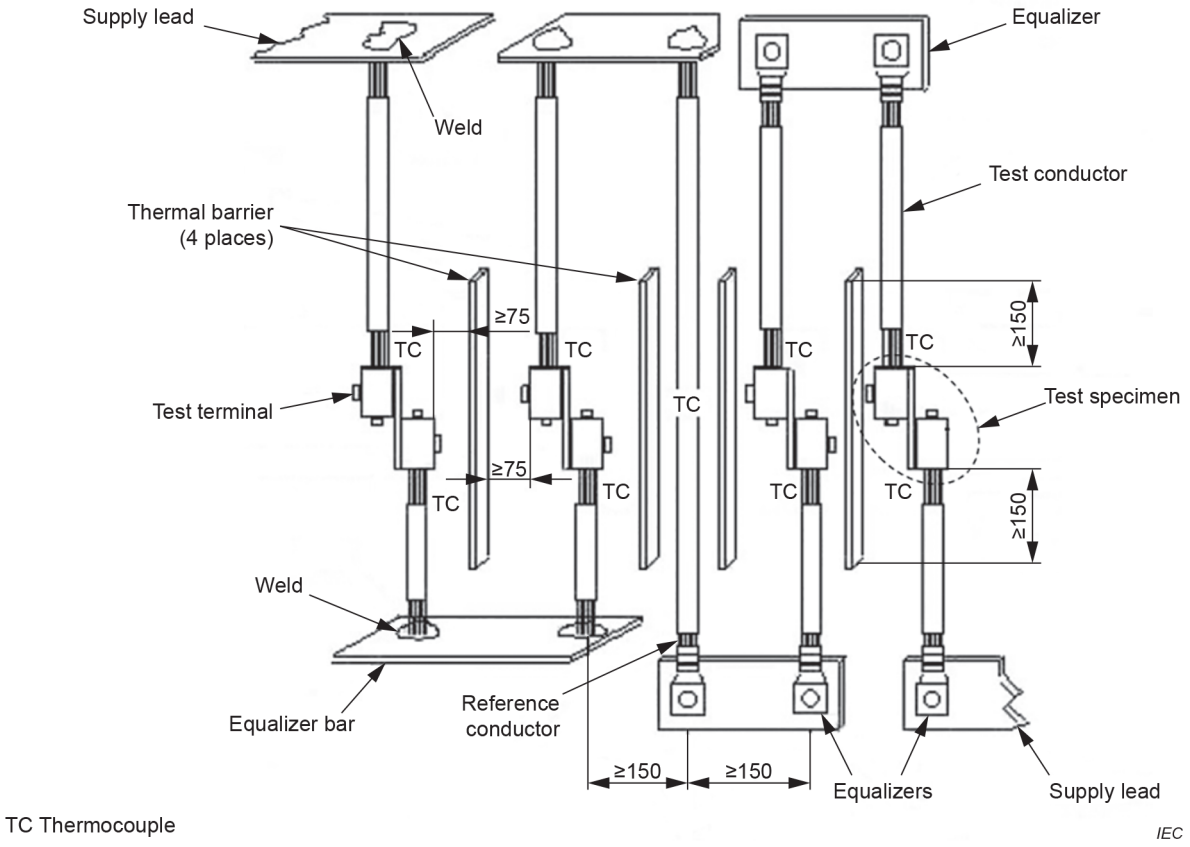


Figure E.1 – General test arrangement

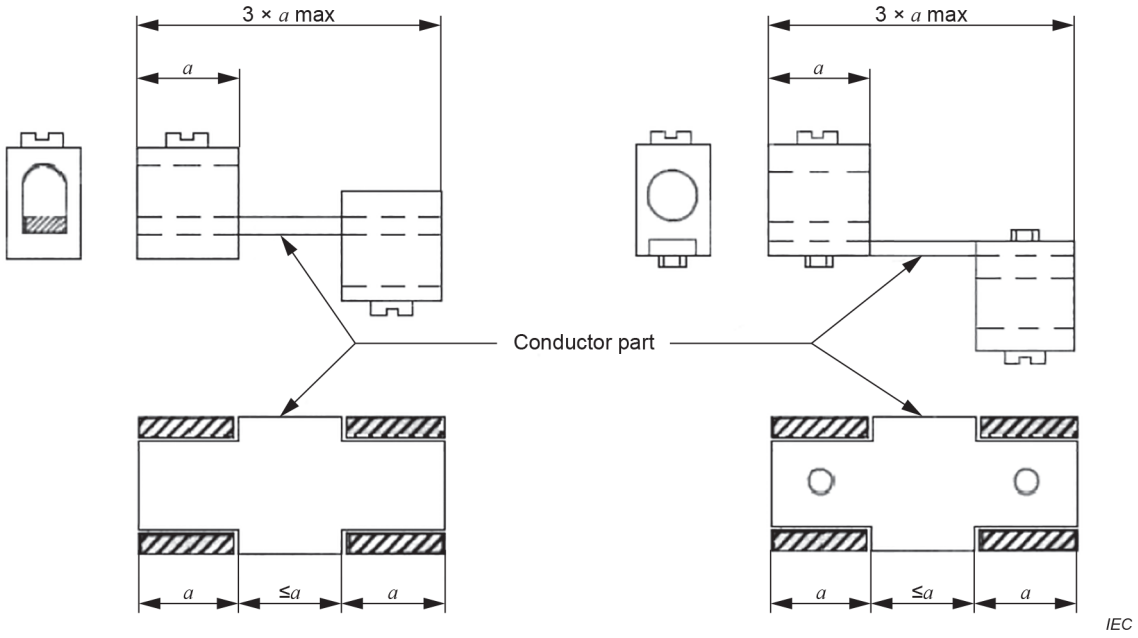


Figure E.2 – Mounting of terminals for the current cycling test

The test is carried out with conductors according to Table E.7 specifying the equivalent aluminium cross-section of conductors.

The length of the test conductor from the point of entry to the terminal specimens to the equalizer shall be as in Table E.2.

Table E.2 – Conductor length for current cycling test as per conductor cross-section

Conductor cross-section		Minimum conductor length
mm^2	AWG/kcmil	mm
0 to 10	30 to 8	200
16 to 25	6 to 3	300
35 to 240	2 to 500	460
Larger than 240	Larger than 500	660

Test conductors are connected in series with a reference conductor of the same cross-section. The length of the reference conductor shall be approximately twice the length of the test conductor. Each free-end of the test and reference conductor(s) not connected to a terminal specimen shall be welded or brazed to a short length of equalizer of cross-section not greater than that given in Table E.3.

90 % of the value of torque stated by the manufacturer or, if not stated, selected in Table 4 of IEC 60947-1:2020, shall be used to connect the aluminium cables to the terminal specimens.

All strands of the conductor shall be welded or brazed to make an electrical connection with the equalizer. As an alternative, tool-applied compression type terminations without welding or brazing may be used for the equalizer if acceptable to the manufacturer.

For an equipment wiring terminal intended for paralleling conductors, the hole spacing pattern in the equalizer shall be identical to the hole spacing pattern in the equipment wiring terminal.

Table E.3 – Equalizer dimensions

Range of test current A		Maximum dimensions (thickness and width) [a]			
		Copper		Aluminium	
>	≤	mm	in	mm	in
0	50	3,2 × 12,7	0,125 × 0,5	3,2 × 12,7	0,125 × 0,5
50	125	3,2 × 25	0,125 × 1	3,2 × 32	0,125 × 1,25
125	225	3,2 × 48	0,125 × 1,875	3,2 × 57	0,125 × 2,25
225	400	6,4 × 38	0,25 × 1,5	6,4 × 50	0,25 × 2
400	600	6,4 × 50	0,25 × 2	6,4 × 76	0,25 × 3
600	800	6,4 × 76	0,25 × 3	6,4 × 102	0,25 × 4
800	1 000	6,4 × 102	0,25 × 4	9,5 × 89	0,375 × 3,5
1 000	1 400	12,7 × 76	0,5 × 3	12,7 × 89	0,5 × 3,5
1 400	2 000	12,7 × 102	0,5 × 4	12,7 × 127	0,5 × 5

[a] The equivalence between mm and inches is only approximative; it is acceptable for the equalizer to comply with either mm or inches columns. Other dimensions may be used providing the current density for the upper limit of the test current (2nd column) exceeds 1,16 A/mm^2 (750 A/in^2) for an aluminium equalizer and 1,55 A/mm^2 (1 000 A/in^2) for a copper equalizer.

The distance between the test and reference conductors shall be at least 150 mm.

The test specimen shall be suspended either horizontally or vertically in free air by supporting the equalizer or equalizer bar by non-conductive supports so as to minimize the tensile load on the terminals. Thermal barriers shall be installed mid- way between the conductors and shall extend 25 mm ± 5 mm widthways and 150 mm ± 10 mm lengthways beyond the terminals (see Figure E.1). Thermal barriers are not required provided the specimens are separated by at least 450 mm. The specimens shall be located at least 600 mm from the floor, wall or ceiling.

The test specimens shall be located in a substantially vibration-free and draught-free environment and at an ambient air temperature between 15 °C and 35 °C. Once the test is started, the maximum permissible variation is ±4 K provided the range limitation is not exceeded.

E.9.2.4 Temperature measurements

Temperature measurements are made by means of thermocouples. Positioning of the thermocouples shall not damage the terminal or the reference conductor.

NOTE 1 Drilling of a small hole and subsequent fastening of the thermocouple is an acceptable method, provided that the performance is not affected and that it is agreed by the manufacturer.

For the measurement of the terminal temperature, the thermocouple shall be located on the conductor entry side of the terminal, close to the contact interface.

For the measurement of the temperature of the reference conductor, the thermocouple shall be located midway between the ends of the conductor, and under its insulation.

The ambient air temperature shall be measured with two thermocouples in such a manner as to achieve an average and stable reading in the vicinity of the test loop without undue external influence. The thermocouples shall be located in a horizontal plane intersecting the specimens, at a minimum distance of 600 mm from them.

NOTE 2 A satisfactory method for achieving a stable measurement is, for example, to attach the thermocouple to unplated copper plates approximately 50 mm × 50 mm, having a thickness between 6 mm and 10 mm.

E.9.2.5 Test method

The test loop shall be subjected to 500 cycles; each cycle consists of an on-period and an off-period as specified, starting at the test current value given in Table E.4.

The on-time shall be the time it takes for the test specimen terminal to reach stable temperatures. The off-time shall be the time it takes to reach room temperature. These times shall be determined in the first 25 cycles of operation. A test specimen terminal has attained a stable temperature when three readings, taken at not less than 10-min intervals, show no more than a 2 °C variation between any two of the readings. The time to temperature stabilization is the first of three readings indicating a stable temperature.

Forced-air cooling may be employed to reduce the off-time, if acceptable to the manufacturer. In that case, it shall be applied to the entire test loop and the resulting temperature of the forced air shall not be lower than the ambient air temperature.

Alternatively, for terminals with single conductors, the on and/or off times in Table E.4 may be used.

Table E.4 – Starting test current for the current cycling test

Cable(s) size			Test current for current cycling test	On- (and off-) times for current cycling
Number	mm^2	AWG/kcmil	A	hours
1	4	12	33	1
1	6	10	45	1
1	10	8	60	1
1	16	6	85	1
1	25	4	110	1
1	35	2	150	1
1	50	0	200	1
1	70	00	230	1
1	95	000	270	1
1	120	250 kcmil	350	1,5
1	150	300 kcmil	390	1,5
1	185	350 kcmil	435	1,5
1	240	500 kcmil	540	2
2	120	250 kcmil	460	-
2	150	300 kcmil	510	-
2	240	500 kcmil	707	-
2	300	600 kcmil	907	-
3	240	500 kcmil	1 060	-

Near the end of each on-period of the first 24 cycles, the temperature of each terminal shall have attained a minimum of 105 °C. When necessary the current shall be adjusted to achieve this condition. If the manufacturer demonstrates that the maximum temperature-rise of the terminals is less than 70 K, the 105 °C temperature may be reduced to this temperature rise plus 35 °C.

This shall be demonstrated by means of a temperature-rise test, in accordance with the general conditions of 9.3.3.3.4 to IEC 60947-1:2020, carried out on the device at the lower of either the rated current of the device or the rated current of the terminals.

This test shall be carried out on a new device equipped with the terminal under consideration and the aluminium conductors as specified in Table E.7. The maximum temperature-rise of all terminals shall be used for determining the target temperature for the current cycling test.

At the 25^{th} cycle, the test current shall be adjusted for the last time and the corresponding temperature, when stabilized at the final load current, shall be recorded as the first measurement. There shall be no further adjustment of the test current for the remainder of the test.

Temperatures shall additionally be recorded after approximately 50, 75, 100, 125, 175, 225, 275, 350, 425, and 500 cycles. The temperature shall be measured during the last 5 min of the on-time. If the size of the set of test specimens or the speed of the data acquisition system is such that not all measurements can be completed within 5 min, the on-time shall be extended as necessary to complete all the measurements.

E.9.2.6 Acceptance criteria

The evaluation of performance is based on both the limit of terminal temperature-rise and the temperature variation (stability factor) during the test.

The stability factor S_f for each of the 11 temperature measurements shall be determined as follows:

– calculate the temperature deviation "d" for the 11 individual temperature measurements by subtracting the associated reference conductor temperature from the terminal temperature;

– calculate the average temperature deviation "D" from the 11 values of "d";

– calculate $S_f = d \quad D$ for each value of "d";

See example of stability factor calculation in Table E.5.

NOTE The value of "d" is positive if the terminal temperature is higher than that of the reference conductor and negative if it is lower.

For each terminal:

– the temperature-rise shall not exceed 125 K, and

– the stability factor S_f shall not exceed ±10 K.

As this is an accelerated aging test, the insulation may be damaged due to high temperatures, but is not considered as a failure of the test.

Table E.5 – Example of stability factor calculation

Temperature measurement	Cycle number	Temperatures		Temperature deviation d = a) − b)	Stability factor $S_f = d - D$ [a]
		a) Terminal [b]	b) Reference conductor		
		°C	°C	K	K
1	25	79	78	1	0,18
2	50	80	77	3	2,18
3	75	78	78	0	–0,82
4	100	76	77	–1	–1,82
5	125	77	77	0	–0,82
6	175	78	77	1	0,18
7	225	79	76	3	2,18
8	275	78	76	2	1,18
9	350	77	78	–1	–1,82
10	425	77	79	–2	–2,82
11	500	81	78	3	2,18

[a] Average temperature deviation $D = \frac{\sum d}{\text{number of measurements}} = \frac{9}{11} = 0,82$.

[b] Example applies to a cable terminal with a maximum temperature of 75 °C.

E.9.3 Mechanical properties of terminals

E.9.3.1 Flexion test

Subclause 9.2.5.3 of IEC 60947-1:2020 applies with the following modification:

The test values shall be in accordance with Table E.6.

E.9.3.2 Pull-out test

Subclause 9.2.5.4 of IEC 60947-1:2020 applies with the following addition:

The test values to be applied shall be in accordance with Table E.6.

Table E.6 – Test values for flexion and pull-out test for cables

Conductor cross-section		Diameter of the bushing hole [a,b]	Height H[a]	Mass	Pulling force
mm^2	AWG/kcmil	mm	mm	kg	N
4	12	9,5	280	0,7	44
6	10	9,5	280	0,7	44
10	8	9,5	280	1,4	44
16	6	12,7	300	4	124
25	4	12,7	300	4,5	160
-	3	14,3	320	5,9	187
35	2	14,3	320	6,8	222
-	1	15,8	343	8,6	271
50	0	15,8	343	9,5	320
70	00	19,1	368	10,4	347
95	000	19,1	368	13,6	432
-	0000	19,1	368	13,6	516
120	250 kcmil	22,2	406	13,6	516
150	300 kcmil	22,2	406	15,4	516
185	350 kcmil	25,4	432	17,2	574
-	400 kcmil	25,4	432	17,2	574
240	500 kcmil	28,6	464	20,4	685
300	600 kcmil	28,6	464	20,4	685

NOTE Table E.6 is based on UL 486E.

[a] Tolerances for height H is ±15 mm, tolerance for diameter of the bushing hole is ±2 mm.

[b] If the bushing hole diameter is not large enough to accommodate the conductor without binding, a bushing having the next larger hole size may be used.

E.9.4 Test for insertability of unprepared round aluminium conductors having the maximum cross-section

Subclause 9.2.5.5 of IEC 60947-1:2020 applies except for the column of flexible conductors in Table 7 of IEC 60947-1:2020.

Table E.7 – Test aluminium cable for test currents up to 800 A [a, d]

Range of test current A		Cable size		
>	≤	Number	mm^2	AWG/kcmil
0	8	1	[c]	[c]
8	12	1	[c]	[c]
12	15	1	4[b]	12[b]
15	20	1	4[b]	12[b]
20	25	1	6[b]	10[b]
25	32	1	10	8
32	50	1	16	6
50	65	1	25	4
65	85	1	35	2
85	100	1	50	0
100	115	1	50	0
115	130	1	70	00
130	150	1	95	000
150	175	1	120	250 kcmil
175	200	1	150	300 kcmil
200	225	1	150	300 kcmil
225	250	1	185	350 kcmil
250	275	1	240	500 kcmil
275	300	2	120	250 kcmil
300	350	2	120	250 kcmil
350	400	2	150	300 kcmil
400	500	2	240	500 kcmil
500	630	2	300	600 kcmil
630	800	3	240	500 kcmil

[a] See 9.3.3.3.4 of IEC 60947-1:2020.

[b] National regulations may require larger sizes. Aluminium cables with cross-sections lower than 10 mm^2 are not recommended per IEC 60364-5-52.

[c] Aluminium cables with cross-sections lower than 4 mm^2 are not recommended.

[d] Test cables for currents above 800 A are under consideration.

Table E.8 – Test aluminium bars for test currents above 150 A and up to 3 150 A [a, f]

Range of test current [g] A		Aluminium bars [b c d]	
>	≤	Number	Dimensions [e] (mm)
400	500	2	25 × 10
500	630	2	30 × 12
630	800	2	40 × 10
800	1 000	2	50 × 10
1 000	1 250	2	80 × 10
1 250	1 600	2	100 × 10
1 600	2 000	3	100 × 10
2 000	2 500	4	100 × 10
2 500	3 150	4	150 × 10[d]

[a] See 9.3.3.3.4 of IEC 60947-1:2020.

[b] For convenience of testing and with the manufacturer's consent, smaller conductors than those given for a stated test current may be used.

[c] Bars are assumed to be arranged with their long faces vertical. Arrangements with long faces horizontal may be used if specified by the manufacturer.

[d] Where four bars are used they shall be in two sets of two bars with not more than 100 mm between pair centres.

[e] Dimensions given are recommendations only. Different sizes can be used upon agreement between manufacturer and user.

[f] For rated currents greater than 3 150 A, agreement shall be reached between manufacturer and user on all relevant items of the test, such as: type of supply, number of phases and frequency (where applicable), cross-sections of test connections. This information shall form part of the test report.

[g] Aluminium bars for test currents below or equal to 400 A are under consideration.

Annex F
(informative)

Power loss

F.1 General

Power loss is not a fundamental characteristic of products covered by this document and need not be marked on the product.

It gives some indication of the heat generated under specified conditions.

Measurement of power loss may be made in free air, on new samples, and be stated in watts.

F.2 Test methods

F.2.1 General

The method of determining power loss given below is based on the measurement of voltage and current. At the discretion of the manufacturer the power loss may be measured using watt meters. This can provide a more accurate value of power loss.

For switches, the voltage used for determining power loss shall be measured between the incoming and outgoing terminals. In the case of the fused devices the voltage shall be measured between the fuse-link terminal and the incoming or outgoing terminal as appropriate. Use of different cable terminals, for example cage clamps and terminals for cable lugs, may lead to different power losses.

The power loss evaluation shall be made under rated current steady-state temperature conditions, < 1 K/h increase, as at the end of the temperature-rise test (see 9.3.4.2). If convenient, the power loss measurements may be made at the end of the temperature-rise test when the temperatures have stabilized.

All phases shall be loaded to rated current when the power loss is measured.

F.2.2 General case for AC switches and/or disconnectors

AC power loss is evaluated as follows, connections being in accordance with Figure F.1.

$$\sum_{k=1}^{k=p} \Delta U_k I_k \cos \varphi_k$$

where

p is the number of phase poles;

k is the pole number;

ΔU is the voltage drop between incoming and outgoing terminals on each pole;

I is the test current which shall be equal to I_n within the tolerances according to 9.3.3.5;

$\cos \varphi$ is the power factor.

F.2.3 General case for AC fused combination units and fuse disconnectors

AC power loss is evaluated as follows, connections being in accordance with Figure F.2.

$$\sum_{k=1}^{k=p} \Delta U_k I_k \cos_{\ k}$$

where

p is the number of phase poles;

k is the pole number;

ΔU = ΔU_a + ΔU_b;

ΔU_a is the voltage drop between the incoming terminal and the adjacent fuse-link terminal;

ΔU_b is the voltage drop between the outgoing device terminal and the adjacent fuse-link terminal;

I is the test current which shall be equal to I_n within the tolerances according to 9.3.3.5;

cos φ is the power factor.

F.2.4 Switches and/or disconnectors of rated current not exceeding 400 A

For AC switches, disconnectors, switch-disconnectors and fuse-combination units of rated current not exceeding 400 A, it is acceptable to use single-phase AC measurement without power factor measurement.

The power loss is evaluated as follows, connections being in accordance with Figure F.3.

$$\sum_{k=1}^{k=p} \Delta U_k I$$

where

p is the number of phase poles;

k is the pole number;

ΔU is the voltage drop between incoming and outgoing terminals on each pole;

I is the test current which shall be equal to I_n within the tolerances according to 9.3.3.5.

F.2.5 Fused combination units and fuse disconnectors of rated current not exceeding 400 A

For AC switches, disconnectors, switch-disconnectors and fuse-combination units of rated current not exceeding 400 A, it is acceptable to use single-phase AC measurement without power factor measurement.

The power loss is evaluated as follows, connections being in accordance with Figure F.4.

$$\sum_{k=1}^{k=p} \Delta U_k I$$

where

p is the number of phase poles;

k is the pole number;

ΔU = ΔU_1 + ΔU_2;

ΔU_1 is the voltage drop between the incoming terminal and the adjacent fuse-link terminal;

ΔU_2 is the voltage drop between the outgoing device terminal and the adjacent fuse-link terminal;

I is the test current which shall be equal to I_n within the tolerances according to 9.3.3.5.

For products complying with this document that are suitable for AC and DC applications, the power loss can be assumed to be the AC value providing the pole configuration is identical. Where this is not the case, for example poles are connected in series to achieve a DC breaking capacity, separate AC and DC tests have to be carried out.

For DC products covered by this document, the DC power loss shall be measured using a DC current.

It is evaluated as in F.2.4 or F.2.5 as applicable.

F.3 Test procedure

The power loss evaluation shall be made under rated current steady-state temperature conditions. If convenient, the power loss measurements may be made during a temperature-rise test.

The connecting leads to measuring instruments (e.g. voltmeter, wattmeter) shall be twisted together. The measuring loop shall be as small as practicable and shall be positioned similarly for each pole.

For evaluating the power loss of three-pole and four-pole AC products complying with this document according to F.2.2 and F.2.3, the test is performed under three-phase current conditions, without current in the fourth pole.

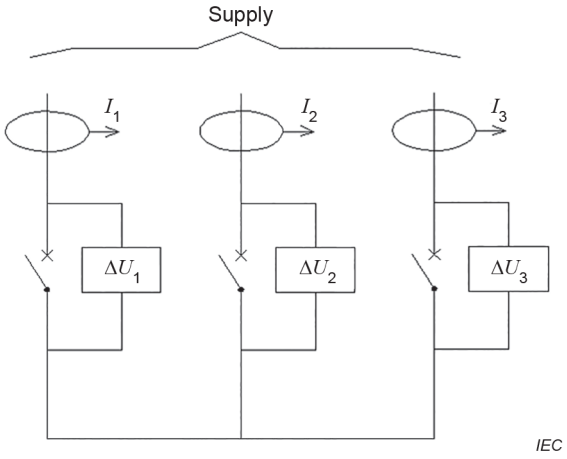


Figure F.1 – Example of power loss measurement according to F.2.2

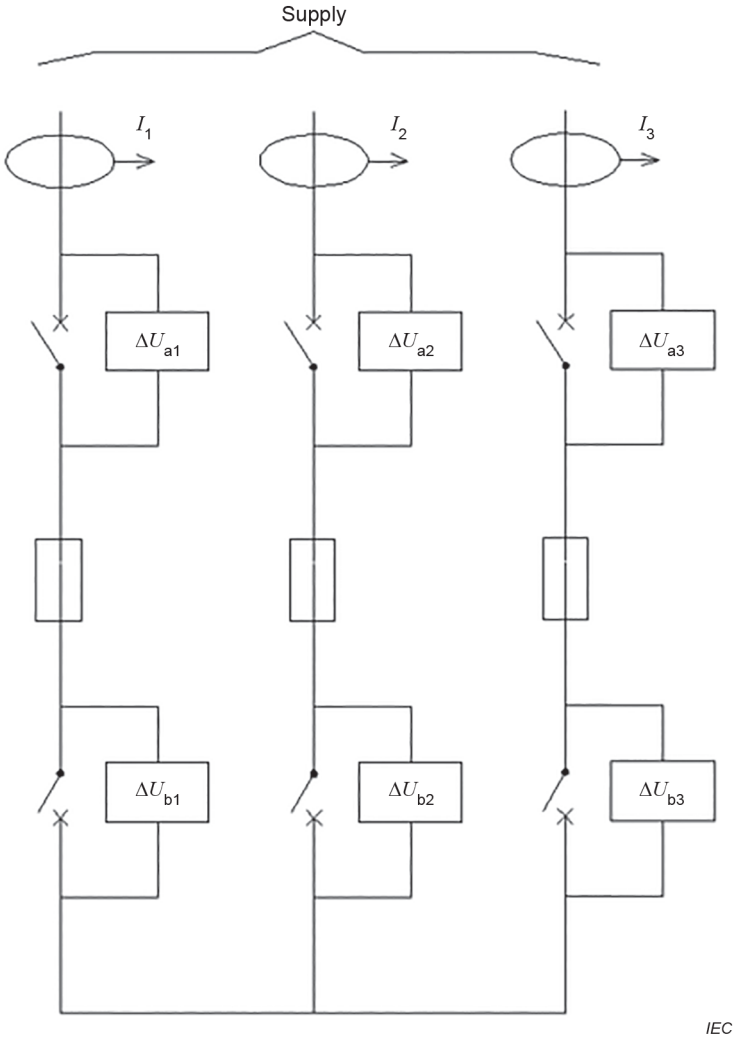


Figure F.2 – Example of power loss measurement according to F.2.3

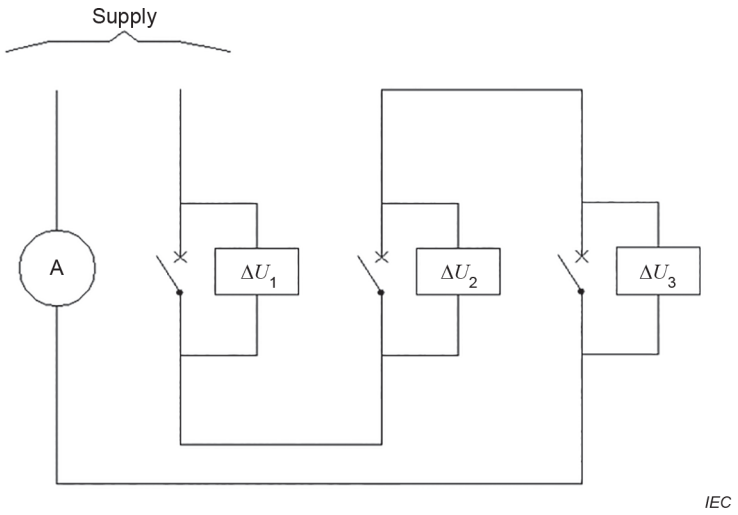


Figure F.3 – Example of power loss measurement according to F.2.4

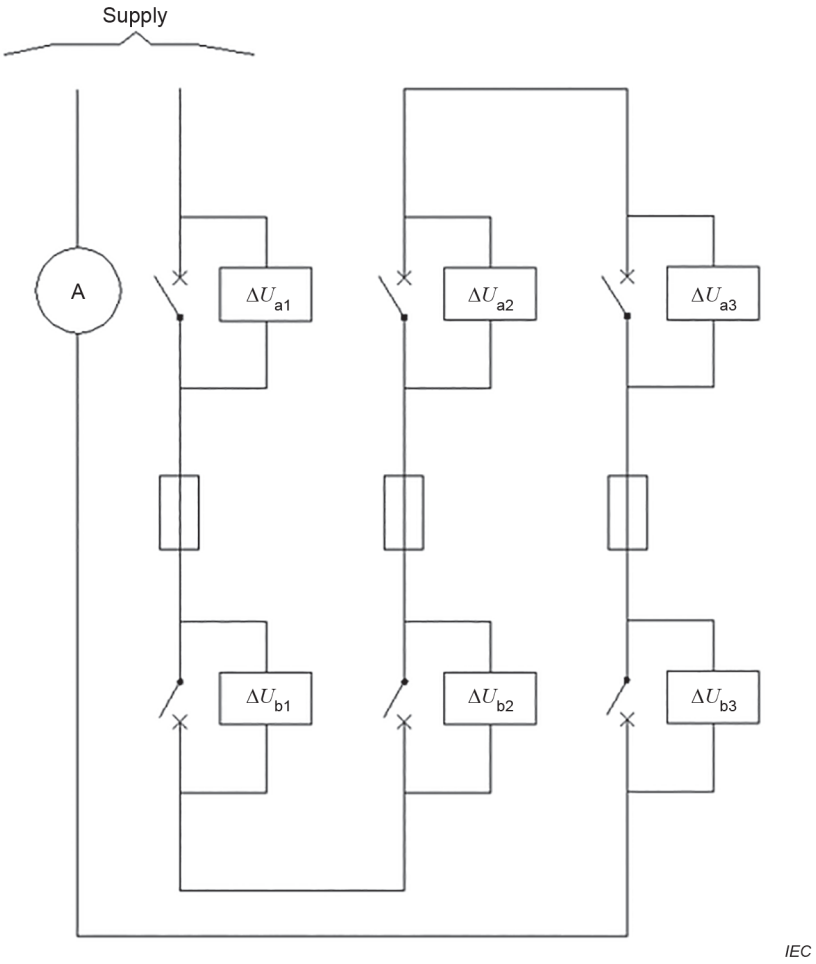


Figure F.4 – Example of power loss measurement according to F.2.5

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[1] Withdrawn.

NATIONAL ANNEX G
(*National Foreword*)

G-1 BIS CERTIFICATION MARKING

G-1.1 The product(s) may also be marked with the Standard mark.

G-1.2 The use of the Standard mark is governed by the provisions of the *Bureau of Indian Standards Act*, 2016 and the Rules and Regulations made thereunder. The details of conditions under which the licence for the use of the Standard Mark may be granted to manufacturers and producers may be obtained from the Bureau of Indian Standards.

Bureau of Indian Standards

BIS is a statutory institution established under the *Bureau of Indian Standards Act*, 2016 to promote harmonious development of the activities of standardization, marking and quality certification of goods and attending to connected matters in the country.

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Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the website-www.bis.gov.in or www.standardsbis.

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Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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