भारतीय मानक

Indian Standard

IS 17123 (Part 2) : 2024
IEC 61800-10 : 2021

Superseding IS/IEC 61800 (Part 2): 2015
IS/IEC 61800 (Part 4): 2002

समायोज्य गति विद्युत चालन यंत्र

भाग 2 सामान्य अपेक्षाएं — समायोज्य गति ए.सी. पावर ड्राइव सिस्टम के लिए रेटिंग विशिष्टी

Adjustable Speed Electrical Power Drive Systems

Part 2 General Requirements — Rating Specifications for Adjustable Speed AC Power Drive Systems

ICS 29.160.30; 29.200

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Power Electronics Sectional Committee, ETD 31

NATIONAL FOREWORD

This Indian Standard (Part 2) which is identical to IEC 61800-2 : 2021 'Adjustable speed electrical power drive systems — Part 2: General requirements — Rating specifications for adjustable speed AC power drive systems' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Power Electronics Sectional Committee and approval of the Electrotechnical Division Council.

IS/IEC 61800 (Part 2) was first published in 2015. This standard has been brought out to align it with the latest version of IEC 61800-2: 2021. This standard supersedes IS/IEC 61800 (Part 2): 2015 and IS/IEC 61800 (Part 4): 2002.

This standard is published in various parts. Other parts in this series are:

Part 1	General requirements — Rating specifications for low-voltage adjustable speed d.c. power drive systems
Part 6	Guide for determination of types of load duty and corresponding current ratings

The text of the IEC Standard has been proposed as suitable for publication as an Indian Standard without deviations. Certain terminologies and 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 exists. The corresponding Indian Standards, which are to be substituted in their respective places, are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60034-1 : 2017 Rotating electrical machines — Part 1: Rating and performance	IS 15999 (Part 1) : 2021/IEC 60034-1 : 2017 Rotating electrical machines: Part 1 Rating and performance	Identical
IEC 60034-9 Rotating electrical machines — Part 9: Noise limits	IS 12065 : 1987 Permissible limits of noise levels for rotating electrical machines	Technically Equivalent
IEC 60038 IEC standard voltages	IS 12360 : 1988 Voltage bands for electrical installations including preferred voltages and frequency	Technically Equivalent
IEC 60050-151 International electrotechnical vocabulary (IEV) — Part 151: Electrical and magnetic devices	IS 1885 (Part 74) : 2012/IEC 60050-151 : 2001 Electrotechnical vocabulary Part 74 Electrical and magnetic devices (*first revision)*	Identical
IEC 60050-161 International electrotechnical vocabulary (IEV) — Part 161: Electromagnetic compatibility	IS 1885 (Part 85) : 2003/IEC 60050-161 : 1990 Electrotechnical vocabulary: Part 85 electromagnetic compatibility	Identical

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60050-441 International electrotechnical vocabulary (IEV) — Part 441: Switchgear, controlgear and fuses	IS 1885 (Part 17) : 2024/IEC 60050-441 : 1984 Electrotechnical vocabulary: Part 17 Switchgear and control gear (*second revision)*	Identical
IEC 60050-551 International electrotechnical vocabulary (IEV) — Part 551: Power electronics	IS 1885 (Part 27) : 2008/IEC 60050-551 : 1998 Electrotechnical vocabulary: Part 27 Power electronics *(third revision)*	Identical
IEC 60050-601 International electrotechnical vocabulary (IEV) — Part 601: Generation, transmission and distribution of electricity — General	IS 1885 (Part 30) : 2023 IEC 60050-601 : 1985 Electrotechnical vocabulary: Part 30 Overhead transmission and distribution of electrical energy	Identical
IEC 60068 (all parts) Environmental testing	IS/IEC 60068 Series Environmental testing	Identical
IEC 60068-2-27 : 2008 Environmental testing — Part 2-27 : Tests — Test Ea and guidance: Shock	IS 9000 (Part 7/Sec 1) : 2018/IEC 60068-2-27 : 2008 Basic environmental testing procedures for electronic and electrical items: Part 7 Impact test, Sec 1 shock (Test Ea.) (*second revision*)	Identical
IEC 60076 (all parts) Power transformers	IS 2026/IEC 60076 (series) Power transformers	Identical
IEC 60079 (all parts) Explosive atmospheres	IS/IEC 60079 (series) Explosive atmospheres	Identical
IEC 60146-1-1 : 2009 Semiconductor converters — General requirement and line commutated converters — Part 1-1: Specification of basic requirements	IS 16539 (Part 1/Sec 1) : 2017 IEC 60146-1-1 : 2009 Semiconductor converters: Part 1 General and line commutated converters, Section 1 Specification of basic requirements	Identical
IEC 60721-3-0 Classification of environmental conditions —Part 3: Classification of groups of environmental parameters and their severities — Introduction	IS/IEC 60721-3-0) : 2020 Classification of environmental conditions: Part 3 Classification of groups of environmental parameters and their severities, Section 0 Introduction	Identical
IEC 60721-3-1:1997 Classification of environmental conditions — Part 3: Classification of groups of environmental parameters and their severities — Section 1: Storage	IS/IEC 60721-3-1) : 2018 Classification of environmental conditions: Part 3 Classification of groups of environmental parameters and their severities: Section 1 Storage	Identical
IEC 60721-3-2:1997 Classification of environmental conditions — Part 3: Classification of groups of environmental parameters and their severities — Section 2: Transportation	IS/IEC 60721-3-2) : 2018 Classification of environmental conditions: Part 3 Classification of groups of environmental parameters and their severities: Section 1 Transportation and handling	Identical
IEC 60721-3-3:1994 Classification of environmental conditions — Part 3: Classification of groups of	IS/IEC 60721-3-3) : 2019 Classification of environmental conditions: Part 3 Classification of	Identical

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
environmental parameters and their severities — Section 3: Stationary use at weather protected locations	groups of environmental parameters and their severities, Section 3 Stationary use at weather protected locations	
IEC 60721-3-4:1995 Classification of environmental conditions — Part 3: Classification of groups of environmental parameters and their severities — Section 4: Stationary use at nonweather protected locations	IS/IEC 60721-3-4) : 2019 Classification of environmental conditions: Part 3 Classification of groups of environmental parameters and their severities, Section 4 Stationary use at non-weather protected locations	Identical
IEC 61800-3 Adjustable speed electrical power drive systems — Part 3: EMC requirements and specific test methods	IS/IEC 61800-3 : 2017 Adjustable speed electrical power drive systems: Part 3 EMC requirements and specific test methods	Identical
IEC 61800-5-1 Adjustable speed electrical power drive systems — Part 5-1: Safety requirements — Electrical, thermal and energy	IS/IEC 61800-5-1) : 2016 Adjustable speed electrical power drive systems: Part 5 Safety requirements, Section 1 Electrical, thermal and energy	Identical
IEC 61800-5-2 Adjustable speed electrical power drive systems — Part 5-2: Safety requirements — Functional	IS/IEC 61800-5-2) : 2020 Adjustable speed electrical power drive systems: Part 5 Safety requirements, Section 2 Functional	Identical
IEC TR 61800-6 Adjustable speed electrical power drive systems — Part 6: Guide for determination of types of load duty and corresponding current ratings	IS 17123 (Part 6) : 2019/IEC TR 61800-6 : 2003 Adjustable speed electrical power drive systems: Part 6 Guide for determination of types of load duty and corresponding current ratings	Identical

The Committee has reviewed the provision of the following International Standard referred in this adopted standard and has decided that it is acceptable for use in conjunction with this standard:

International Standard	*Title*
IEC 60050-112	International electrotechnical vocabulary (IEV) — Part 112: Quantities and units
IEC 60050-113 : 2011	International electrotechnical vocabulary (IEV) — Part 113: Physics for electrotechnology
IEC 60050-114	International electrotechnical vocabulary (IEV) — Part 114: Electrochemistry
IEC 60050-442	International electrotechnical vocabulary (IEV) — Part 442: Electrical accessories
IEC TR 60146-1-2	Semiconductor convertors — General requirement and line commutated convertors — Part 1-2: Application guidelines
IEC 61800-7 (all parts)	Adjustable speed electrical power drive systems — Part 7: Generic interface and use of profiles for power drive systems
IEC TS 61800-8	Adjustable speed electrical power drive systems — Part 8: Specification of voltage on the power interface
IEC 61800-9-1	Adjustable speed electrical power drive systems — Part 9-1:

International Standard	*Title*
	Ecodesign for power drive systems, motor starters, power electronics and their driven applications — General requirements for setting energy efficiency standards for power driven equipment using the extended product approach (EPA) and semi analytic model (SAM)
IEC 61800-9-2	Adjustable speed electrical power drive systems — Part 9-2: Ecodesign for power drive systems, motor starters, power electronics and their driven applications — Energy efficiency indicators for power drive systems and motor starters
IEC TS 62578	Power electronics systems and equipment — Operation conditions and characteristics of active infeed converter (AIC) applications including design recommendations for their emission values below 150 kHz

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.

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

0.1 General

This document is part of the IEC 61800 series specifying requirements for adjustable *speed* electrical *power drive systems* (*PDS*). Since the publication of the second edition of IEC 61800-2, several documents of the IEC 61800 series have been developed and maintained, which has resulted in outdated references and conflicting requirements across the IEC 61800 series.

This document contains general requirements for *PDS*s intended to feed AC *motors* and with rated *converter* input voltages (line-to-line voltage) up to 35 000 V AC.

PDSs intended to feed DC *motors* are covered by IEC 61800-1.

0.2 Consistency of requirement

This document specifies requirements for *PDS*s under its scope for the identified topics not covered by any other of the standards in the IEC 61800 series.

The following requirements are covered by other standards in the IEC 61800 series:

- DC *PDS* requirements are covered by IEC 61800-1;
- EMC requirements are covered by IEC 61800-3;
- general safety requirements are covered by IEC 61800-5-1;
- functional safety requirements are covered by IEC 61800-5-2;
- type of load duty guidance is covered by IEC TR 61800-6;
- interface and use of profiles requirements are covered by IEC 61800-7 (all parts);
- *power interface* voltage specification is covered by IEC TS 61800-8;
- ecodesign energy *efficiency* requirements of drive system are covered by IEC 61800-9 (all parts).

Generally, this document provides a basic description of topics and refers to the relevant standard for specific requirement. This is done in order to ensure consistency, to avoid conflicting requirement within IEC 61800 (all parts) and to optimize future maintenance of the documents.

As part of the work inside SC 22G MT9, this document defines basic definitions used across the IEC 61800 series. For issues related to *active infeed converters,* IEC TS 62578 has been considered.

As a result of the development of the IEC 61800 series of standards, the need to reference documents outside the series has decreased and especially the need to reference the IEC 60146 (all parts) has decreased dramatically.

0.3 Tool for agreement between *customer* and *manufacturer*

This document provides a non-exhaustive list of requirements to aid in the development of a functional specification between responsible parties. Each topic should be individually specified by the *responsible party*(ies) as a compliance requirement where appropriate for the intended application. When the *manufacturer* is the only *responsible party*, for any reason, the *manufacturer* may choose to select the specific sections of this document which are relevant for the intended application.

BDM/CDM/PDS may be built into a final installation or imbedded into an extended product as a component. The following are example applications: lift and hoist, machinery, conveyor, switchgears, heating and ventilation, pump, wind, tidal and marine propulsion applications.

In every application, an identification of the environmental conditions under which the product is stored, transported and operated is essential for the proper specification of the *BDM/CDM/PDS*. The environmental conditions considered should include at least those defined in IEC 60721 (all parts) and EMC.

Indian Standard

ADJUSTABLE SPEED ELECTRICAL POWDER DRIVE SYSTEMS

PART 2 GENERAL REQUIREMENTS — RATING SPECIFICATIONS FOR ADJUSTABLE SPEED AC POWDER DRIVE SYSTEMS

1 Scope

This part of IEC 61800 applies to adjustable *speed* electric AC *power drive systems*, which include semiconductor power conversion and the means for their control, protection, monitoring, measurement and the AC *motor*s.

It applies to adjustable *speed* electric *power drive systems* intended to feed AC *motors* from a *BDM or CDM* connected to line-to-line voltages up to and including 35 kV AC 50 Hz or 60 Hz and/or voltages up to and including 1,5 kV DC input side.

NOTE Adjustable *speed* electric DC *power drive systems* intended to feed DC *motors* are covered by IEC 61800-1.

This documents defines and describes a non-exhaustive list of criteria for the selection of *BDM/CDM/PDS* performance and functional attributes. This list is reviewed by the responsible parties to determine considerations for the design of device(s), equipment or system(s) with related testing specification. It also suggests a selection of performance and functional attributes for driven equipment and extended products. The performance and functional attributes focus on the following categories:

- principal parts topology and classification of the *PDS*;
- ratings, performance and functionality;
- specifications for the environment in which the *PDS* is intended to be installed and operated;
- other specifications which might be applicable when specifying a complete *PDS*.

Traction applications and electric vehicles are excluded from the scope of this document.

This document provides a non-exhaustive list from which minimum requirements can be used for the development of a specification between *customer* and *manufacturer* based on the application requirements. This same non-exhaustive list can be used by a *manufacturer* to determine the minimum requirements for a commoditised *BDM/CDM/PDS* without *customer* interaction based on the specified application of that *BDM/CDM/PDS*.

For some aspects which are covered by specific *PDS* product standards in the IEC 61800 series, this document provides a short introduction and reference to detailed requirements in these product standards.

This applies to the following aspects:

- EMC requirements are covered by IEC 61800-3;
- general safety requirements are covered by IEC 61800-5-1;
- functional safety requirements are covered by IEC 61800-5-2;
- type of load duty guidance is covered by IEC TR 61800-6;
- interface and use of profiles requirements are covered by IEC 61800-7 (all parts);
- power interface voltage specification is covered by IEC TS 61800-8;

- ecodesign energy efficiency requirements of drive system are covered by IEC 61800-9 (all parts).

2 Normative references

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

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

IEC 60038, *IEC standard voltages*

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

IEC 60050-113:2011, *International Electrotechnical Vocabulary (IEV) – Part 113: Physics for electrotechnology* (available at www.electropedia.org)

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

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

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

IEC 60050-192, *International Electrotechnical Vocabulary (IEV) – Part 191: Dependability* (available at www.electropedia.org)

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

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

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

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

IEC 60068 (all parts), *Environmental testing*

IEC 60068-2-27:2008, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*

IEC 60076 (all parts), *Power transformers*

IEC 60076-11, *Power transformers – Part 11: Dry-type transformers*

IEC 60079 (all parts), *Explosive atmospheres*

IEC 60146-1-1, *Semiconductor convertors – General requirement and line commutated convertors – Part 1-1: Specification of basic requirements*

IEC TR 60146-1-2, *Semiconductor convertors – General requirement and line commutated convertors – Part 1-2: Application guidelines*

IEC 60721-3-0, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Introduction*

IEC 60721-3-1:1997, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 1: Storage*

IEC 60721-3-2:1997, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 2: Transportation*

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

IEC 60721-3-4:1995, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 4: Stationary use at non-weather protected locations*
IEC 60721-3-4:1995/AMD1:1996

IEC 61800-3, *Adjustable speed electrical power drive systems – Part 3: EMC requirements and specific test methods*

IEC 61800-5-1, *Adjustable speed electrical power drive systems – Part 5-1: Safety requirements – Electrical, thermal and energy*

IEC 61800-5-2:2016, *Adjustable speed electrical power drive systems – Part 5-2: Safety requirements – Functional*

IEC TR 61800-6, *Adjustable speed electrical power drive systems – Part 6: Guide for determination of types of load duty and corresponding current ratings*

IEC 61800-7 (all parts), *Adjustable speed electrical power drive systems – Part 7: Generic interface and use of profiles for power drive systems*

IEC 61800-7-1, *Adjustable speed electrical power drive systems – Part 7-1: Generic interface and use of profiles for power drive systems – Interface definition*

IEC TS 61800-8, *Adjustable speed electrical power drive systems – Part 8: Specification of voltage on the power interface*

IEC 61800-9-1, *Adjustable speed electrical power drive systems – Part 9-1: Ecodesign for power drive systems, motor starters, power electronics and their driven applications – General requirements for setting energy efficiency standards for power driven equipment using the extended product approach (EPA) and semi analytic model (SAM)*

IEC 61800-9-2, *Adjustable speed electrical power drive systems – Part 9-2: Ecodesign for power drive systems, motor starters, power electronics and their driven applications – Energy efficiency indicators for power drive systems and motor starters*

IEC TS 62578:2015, *Power electronics systems and equipment – Operation conditions and characteristics of active infeed converter (AIC) applications including design recommendations for their emission values below 150 kHz*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-112, IEC 60050-113, IEC 60050-114, IEC 60050-151, IEC 60050-161, IEC 60050-191, IEC 60050-441, IEC 60050-442, IEC 60050-551, IEC 60050-601, IEC 60146-1-1, IEC TR 60146-1-2, and the following apply.

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

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

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Table 1 – List of general terms

3.4	basic drive module (BDM)	3.2	mains supply	3.96	type test
3.6	complete drive module (CDM)	3.51	port for process measurement and control	3.84	routine test
3.29	inverter	3.54	power interface	3.85	sample test
3.7	converter, <of the BDM>	3.88	signal interface	3.1	acceptance test
3.80	rectifier <of the BDM>	3.56	product packaging	3.97	witness test
3.10	DC link	3.86	shipping packaging	3.5	commissioning test
3.3	active infeed converter (AIC)	3.81	regeneration	3.89	special test
3.52	power drive system (PDS)			3.82	resolution
3.30	low-voltage BDM/CMD/PDS <for AC motor>	3.53	power factor (λ)	3.83	responsible party
3.16	high-voltage BDM/CMD/PDS <for AC motor>	3.94	total harmonic distortion (THD)	3.8	customer, <of the BDM/CDM/PDS>
3.28	integrated PDS	3.87	short circuit ratio (R_{SC})	3.14	end user
3.36	motor electric motor	3.12	efficiency <of the CDM>	3.31	manufacturer, <of the BDM/CDM/PDS>
3.27	installation	3.13	efficiency <of the PDS>	3.37	original equipment manufacturer (OEM)
3.50	port	3.46	output overload capability	3.92	system integrator
3.55	power port	3.91	stimulus		

NOTE This document contains the fundamental definitions used across IEC 61800 (all parts) in a way that they can be used in future revisions of all IEC 61800 standards.

Table 2 – List of input ratings of *BDM/CDM/PDS*

3.21	input current <BDM> (I_{v})	3.66	rated input voltage <CDM/PDS> (U_{LN})	3.58	rated input active power <CDM/PDS> (P_{LN})
3.61	rated input current <BDM> (I_{vN})	3.17	input active power <BDM> (P_{v})	3.60	rated input apparent power <CDM/PDS> (S_{LN})
3.22	input current <CDM/PDS> (I_{L})	3.19	input apparent power <BDM> (S_{v})	3.23	input frequency <BDM> (f_{v})
3.62	rated input current <CDM/PDS> (I_{LN})	3.18	input active power <CDM/PDS> (P_{L})	3.63	rated input frequency <BDM> (f_{vN})
3.25	input voltage <BDM> (U_{v})	3.20	input apparent power <CDM/PDS> (S_{L})	3.24	input frequency <CDM/PDS> (f_{L})
3.65	rated input voltage <BDM> (U_{vN})	3.57	rated input active power <BDM> (P_{vN})	3.64	rated input frequency <CDM/PDS> (f_{LN})
3.26	input voltage <CDM/PDS> (U_{L})	3.59	rated input apparent power <BDM> (S_{vN})		

NOTE Subscripts follow the concept of IEC 60146-1-1.

Table 3 – List of output ratings of *BDM/CDM/PDS*

3.42	output current <BDM> (I_{a})	3.38	Output active power <BDM> (P_{a})	3.41	output apparent power <CDM> (S_{A})
3.71	rated output current <BDM> (I_{aN})	3.67	rated output active power <BDM> (P_{aN})	3.70	rated output apparent power <CDM> (S_{AN})
3.43	output current <CDM> (I_{A})	3.39	output active power <CDM> (P_{A})	3.44	output frequency <BDM> (f_{a})
3.72	rated output current <CDM> (I_{AN})	3.68	rated output active power <CDM> (P_{AN})	3.73	rated output frequency <BDM> (f_{aN})
3.48	output voltage <BDM> (U_{a1})	3.47	output power <PDS> (P_{s})	3.45	output frequency <CDM> (f_{A})
3.76	rated output voltage <BDM> (U_{aN1})	3.75	rated output power <PDS> (P_{sN})	3.74	rated output frequency <CDM> (f_{AN})
3.49	output voltage <CDM> (U_{A1})	3.40	output apparent power <BDM> (S_{a})	3.46	output overload capability
3.77	rated output voltage <CDM> (U_{AN1})	3.69	rated output apparent power <BDM> (S_{aN})		

NOTE Subscripts follow the concept of IEC 60146-1-1

Table 4 – List of *motor speed* and *torque* ratings

3.95	two quadrant operation [b]	3.35	minimum speed <of a motor> (N_{Min})	3.93	torque <of a motor> (*M*)
3.15	four quadrant operation [b]	3.34	minimum rated speed <of a motor> (N_{NMin})	3.79	rated torque <of a motor> (M_N)
3.90	speed <of a motor> (N)	3.32	maximum rated safe speed <of a motor> (N_{SNMax})	3.9	DC braking
3.78	rated speed <of a motor> (N_N)	3.33	maximum rated speed <of a motor> (N_{NMax})	3.11	dynamic braking

NOTE 1 Subscripts follow the concept of IEC 60146-1-1.

NOTE 2 See also Figure 10, 5.3.3.2.

3.1
acceptance test
contractual test to prove to the *customer* that the device meets certain conditions of its specification

[SOURCE: IEC 60050-151:2001, 151-16-23, modified – The word "item" has been replaced by the word "device".

3.2
mains supply
low or high-voltage power distribution *system* for supplying power to a *BDM/CDM/PDS*

SEE Figure 3.

3.3
active infeed converter
AIC
self-commutated power electronic *converter* which can convert electric power in both directions and which can control the reactive power or the *power factor*

Note 1 to entry: An active infeed *converter* can be of any technology, topology, voltage and size containing either current or voltage source DC side which work in generation and regeneration.

Note 2 to entry: Some of them can additionally control the harmonics to reduce the distortion of an applied voltage or current.

Note 3 to entry: Basic topologies may be realized as a Voltage Source *Converter* (VSC) or a Current Source *Converter* (CSC).

Note 4 to entry: In IEC 60050-551, these terms (VSC and CSC) are defined as voltage stiff AC / DC *converter* [551-12-03] and current stiff AC / DC *converter* [551-12-04]. Most of the AICs are bi-directional *converter*s and have sources on the DC side

Note 5 to entry: In some literature *active infeed converters* are also known as active front end (AFE) *converters*.

[SOURCE: IEC TS 62578:2015, 3.5, modified – Some words in the definition have been moved to Note 1 to entry.]

3.4
basic drive module
BDM
electronic power *converter* and related control, connected between an electric supply and a *motor*

SEE Figure 3.

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

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

3.5
commissioning test
test on a device or equipment carried out on site, to prove the correctness of *installation* and operation

[SOURCE: IEC 60050-411:1996, 411-53-06, modified – The word "machine" has been replaced by "device".]

3.6
complete drive module
CDM
drive module consisting of, but not limited to, the *BDM* and extensions such as protection devices, transformers and auxiliaries, but excluding the *motor* and the sensors which are mechanically coupled to the *motor* shaft

SEE Figure 3.

3.7
converter
<of the *BDM*> unit which changes the form of electrical power supplied from the *mains supply* to the form required by the *motor*(s) by changing one or more of the following; voltage, current and/or frequency

SEE Figure 3.

Note 1 to entry: The *converter* comprises electronic commutating devices and their associated commutation circuits. It is controlled by transistors or thyristors or any other power switching semiconductor devices.

Note 2 to entry: The *converter* can be line-commutated or self-commutated and can consist for example of one or more *rectifiers*.

3.8
customer
<of the *BDM/CDM/PDS*> *original equipment manufacturer (OEM)*, *system integrator* or *end user* specifying and purchasing a *BDM/CDM/PDS* from the *BDM/CDM/PDS manufacturer*

See Figure 1.

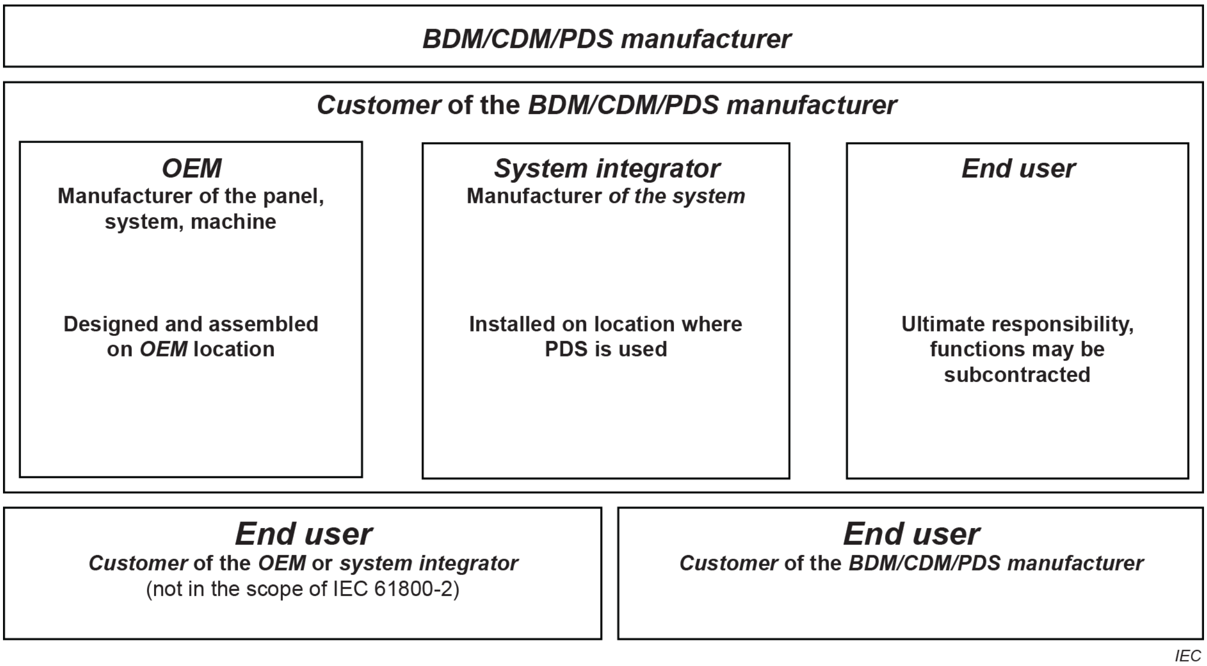


Figure 1 – *BDM/CDM/PDS manufacturer*/*customer* relationship

3.9
DC braking
process of converting the rotational energy of the load to electrical energy dissipated in the rotor by injection of DC current into the stator

3.10
DC link
power DC circuit linking the input *converter* and the output *converter* of an indirect *converter*, consisting of capacitors and/or reactors to reduce DC voltage ripple or DC current ripple

See Figure 3.

3.11
dynamic braking
method used to transfer energy generated when the load controlled by a PDS is slowed or stopped

Note 1 to entry: *Dynamic braking* includes resistive braking, regenerative braking, etc.

3.12
efficiency
<of the *CDM*> ratio of the total electrical power at the *CDM power interface* of the *motor* terminals to the total power at the *mains supply port*

Note 1 to entry: See feeding line in Figure 3.

Note 2 to entry: *Efficiency* is usually expressed as a percentage.

Note 3 to entry: IEC 61800-9-1 and IEC 61800-9-2 define power losses of the CDM and PDS. This document will change in the next edition to consider only power losses for the *BDM/CDM/PDS*, not efficiency. IEC 61800-9-1 and IEC 61800-9-2 should be used for power losses consideration of *CDM/PDS*. Because the BDM is a portion of the *CDM*, it is correct to calculate power losses for the *BDM* as well.

3.13
efficiency
<of the *PDS*> ratio of the mechanical power at the *motor* shaft to the total electrical power at the *mains supply port*

Note 1 to entry: See feeding line in Figure 3.

Note 2 to entry: *Efficiency* is usually expressed as a percentage.

Note 3 to entry: IEC 61800-9-1 and IEC 61800-9-2 define power losses of the *CDM* and *PDS*. This standard will change in the next edition to consider only power losses for the *BDM/CDM/PDS*, not efficiency. IEC 61800-9-1 and IEC 61800-9-2 should be used for power losses consideration of *CDM/PDS*. Because the *BDM* is a portion of the *CDM*, it is correct to calculate power losses for the *BDM* as well.

3.14
end user
entity who has ultimate responsibility for the *installation*, operation and maintenance of the *PDS*

SEE Figure 1.

3.15
four quadrant operation
converter operation of a machine as a *motor* or a generator in either direction of machine rotation

See Figure 2.

Note 1 to entry: *Four quadrant operation* involves operation in quadrants I, II, III and IV as shown in Figure 2.

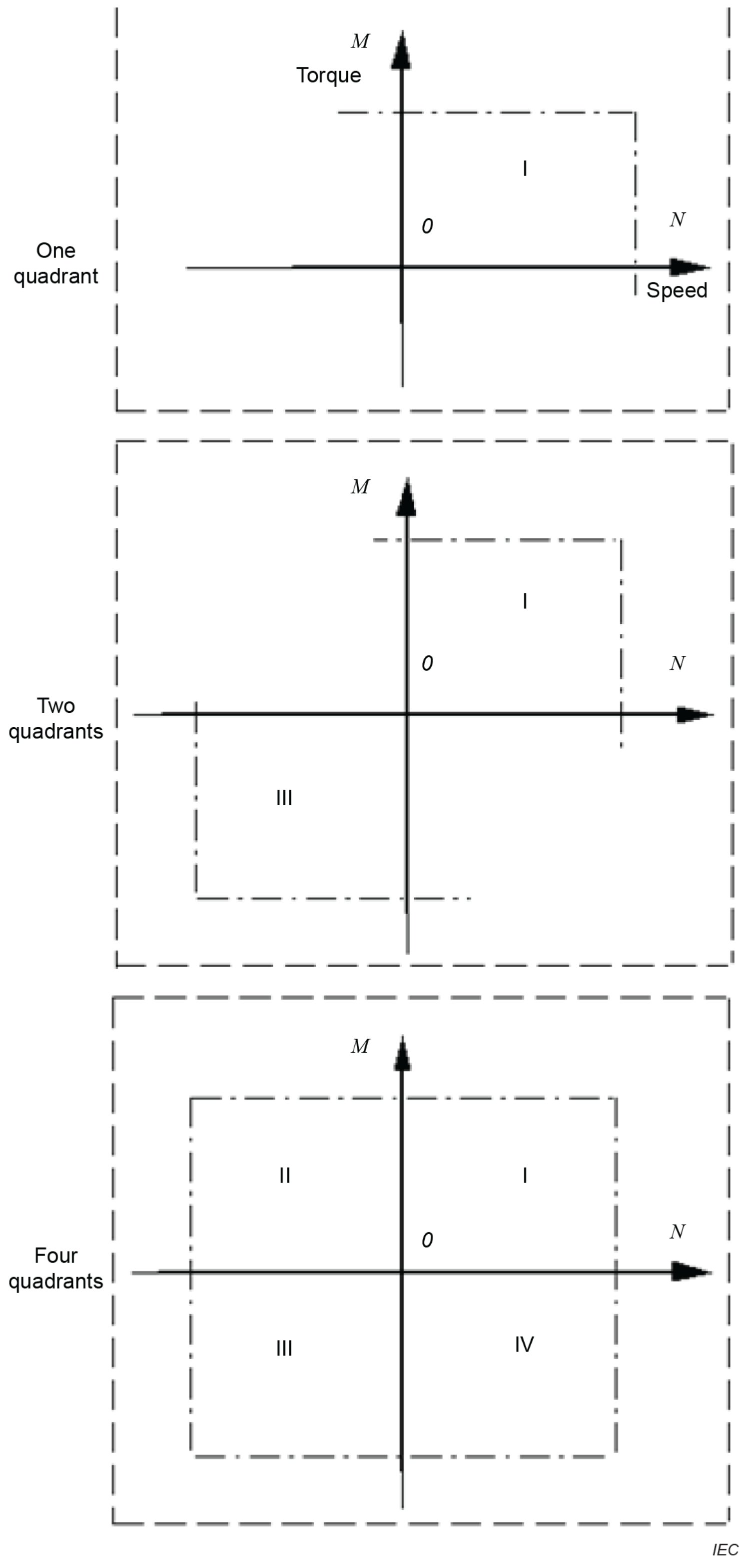


Figure 2 – Operating quadrants

3.16
high-voltage BDM/CDM/PDS
<for AC *motor*> *basic drive module/complete drive module/power drive system having a port voltage* above 1 kV AC 50 Hz or 60 Hz or above 1,5 kV DC

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

Note 2 to entry: See Table 5 for explanation.

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

Note 4 to entry: In the United States, the voltage range of the scope of this document is considered medium voltage.

Note 5 to entry: The term "high voltage" is abbreviated HV.

Table 5 – Basic classification of PDS by voltage

***BDM/CDM* voltage ratings**		**Classification of *PDS* by voltage**
Input U_{vN} / U_{LN}	**Output** U_{aN1}/U_{AN1}	
Low-voltage	Low-voltage	Low-voltage
Low-voltage	High-voltage	High-voltage
High-voltage	Low-voltage	High-voltage
High-voltage	High-voltage	High-voltage

3.17
input active power
P_v
<*BDM*> power determined by the fundamental components of voltage and current at the supply terminals of the *BDM*

3.18
input active power
P_L
<*CDM/PDS*> power determined by the fundamental components of voltage and current at the supply terminals of the *CDM/PDS*

3.19
input apparent power
S_v
<*BDM*> power determined by the RMS values of voltage and current at the supply terminals of the *BDM*

3.20
input apparent power
S_L
<*CDM/PDS*> power determined by the RMS values of voltage and current at the supply terminals of *CDM/PDS*

3.21
input current
I_v
<*BDM*> RMS value of current at the supply terminals of the *BDM*

3.22
input current
I_L
<*CDM/PDS*> RMS value of current at the supply terminals of the *CDM/PDS*

3.23
input frequency
f_V
<*BDM*> frequency of the power input to the *BDM*

3.24
input frequency
f_L
<*CDM/PDS*> frequency of the power input to the *CDM/PDS*

3.25
input voltage
U_V
<*BDM*> RMS input line-to-line voltage at the supply terminals of the *BDM*

3.26
input voltage
U_L
<*CDM/PDS*> RMS input line-to-line voltage at the supply terminals of the *CDM/PDS*

3.27
installation
apparatus or a set of devices and/or apparatuses associated in a given location to fulfil specified purposes, including all means for their satisfactory operation

See Figure 3.

Note 1 to entry: The words "act of installing" are used in this document to denote the process of installing a *PDS*.

[SOURCE: IEC 60050-151:2001, 151-11-26, modified – The reference to Figure 3 has been added, as well as Note 1 to entry.]

3.28
integrated PDS
power drive system where *motor* and *BDM/CDM* are combined into a single unit

3.29
inverter
electric energy *converter* that changes direct electric current to single-phase or polyphase alternating currents

See Figure 3.

[SOURCE: IEC 60050-151:2001, 151-13-46]

3.30
low-voltage BDM/CDM/PDS
<for AC *motor*> *basic drive module/complete drive module/power drive system having a port voltage* less than or equal to 1 kV AC 50 Hz or 60 Hz or 1,5 kV DC

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

Note 2 to entry: The term "low-voltage" is abbreviated LV.

3.31
manufacturer
<of the *BDM/CDM/PDS*> entity which designs and builds all or part of a *BDM/CDM/PDS*

SEE Figure 1.

3.32
maximum rated safe speed
N_{SNMax}
<of a *motor*> maximum *speed* at which the *motor* may be operated continuously

Note 1 to entry: Operation above the *maximum rated safe speed* could lead to a hazard.

Note 2 to entry: See also Figure 10 and 5.3.3.2.

3.33
maximum rated speed
N_{NMax}
<of a *motor*> maximum *speed* specified by the *PDS manufacturer*

Note 1 to entry: This might include operation in the field weakening mode, at a *speed* higher than the *rated speed*, but with torque lower than *rated torque* (constant power region).

Note 2 to entry: When operating a *motor* at speeds above *rated speed*, the mechanical stress increases and the expected lifetime of the bearings may be reduced. Fine balance of the *motor* as well as service of the *motor* should be considered. See also IEC 60034-1.

Note 3 to entry: See also Figure 10 and 5.3.3.2.

3.34
minimum rated speed
N_{NMin}
<of a *motor*> minimum allowed *speed* at which the *motor* is able to continuously deliver *rated torque*, without overheating the *motor*

Note 1 to entry: See also Figure 10 and 5.3.3.2.

3.35
minimum speed
N_{Min}
<of a *motor*> minimum allowed *speed* of the *motor* at which the *motor* is able to continuously deliver *torque*, without overheating the *motor*

Note 1 to entry: See also Figure 10 and 5.3.3.2.

Note 2 to entry: Operating at minimum *speed* may also include operation with reduced *torque*.

3.36
motor
electric motor
electric machine intended to transform electric energy into mechanical energy

SEE Figure 3.

Note 1 to entry: For the purposes of this document, the *motor* includes all sensors which are mounted on it and which are relevant for supporting the operating mode and interacting with a *CDM.*

3.37
original equipment manufacturer
OEM
entity which designs and manufactures series of machines, panels or systems incorporating one or more *PDS*s

SEE Figure 1.

3.38
output active power
P_a
<*BDM*> power determined by the fundamental components of voltage and current at the *motor* side of the *BDM*

3.39
output active power
P_A
<*CDM*> power determined by the fundamental components of voltage and current at the *motor* side of the *CDM*

3.40
output apparent power
S_a
<*BDM*> power determined by the RMS values of voltage and current at the *motor* side of the *BDM*

3.41
output apparent power
S_A
<*CDM*> power determined by the RMS values of voltage and current at the *motor* side of the *CDM*

3.42
output current
I_a
<*BDM*> RMS value of the current at the *motor* side of the *BDM*

3.43
output current
I_A
<*CDM*> RMS value of the current at the *motor* side of the *CDM*

3.44
output frequency
f_a
<*BDM*> fundamental frequency at the *motor* side of the *BDM*

Note 1 to entry: The frequency is usually specified as the operating range by the *manufacturer*.

3.45
output frequency
f_A
<*CDM*> fundamental frequency at the *motor* side of the *CDM*

Note 1 to entry: The frequency is usually specified as the operating range by the *manufacturer*.

3.46
output overload capability
maximum *output current* which can be supplied, for a specified period of time, without exceeding established limitations under prescribed operating conditions

3.47
output power
P_s
<*PDS*> (mechanical) power of the *PDS* determined by the *torque* and *speed* at the *motor* shaft

3.48
output voltage
U_{a1}
<*BDM*> RMS value of the rated fundamental voltage at the *motor* side of the *BDM*

3.49
output voltage
U_{A1}
<*CDM*> RMS value of the rated fundamental voltage at the *motor* side of the *CDM*

3.50
port
access to a device or network where electromagnetic energy or signals may be supplied or received or where the device or network variables may be observed or measured

3.51
port for process measurement and control
input/output (I/O) *port* for conductor or cable which connects the process to the *PDS*

3.52
power drive system
PDS
system consisting of one or more *complete drive module*(s) (*CDM*) and a *motor* or *motor*s

SEE Figure 3.

Note 1 to entry: Any sensors which are mechanically coupled to the *motor* shaft are also part of the PDS; however, the driven equipment is not included.

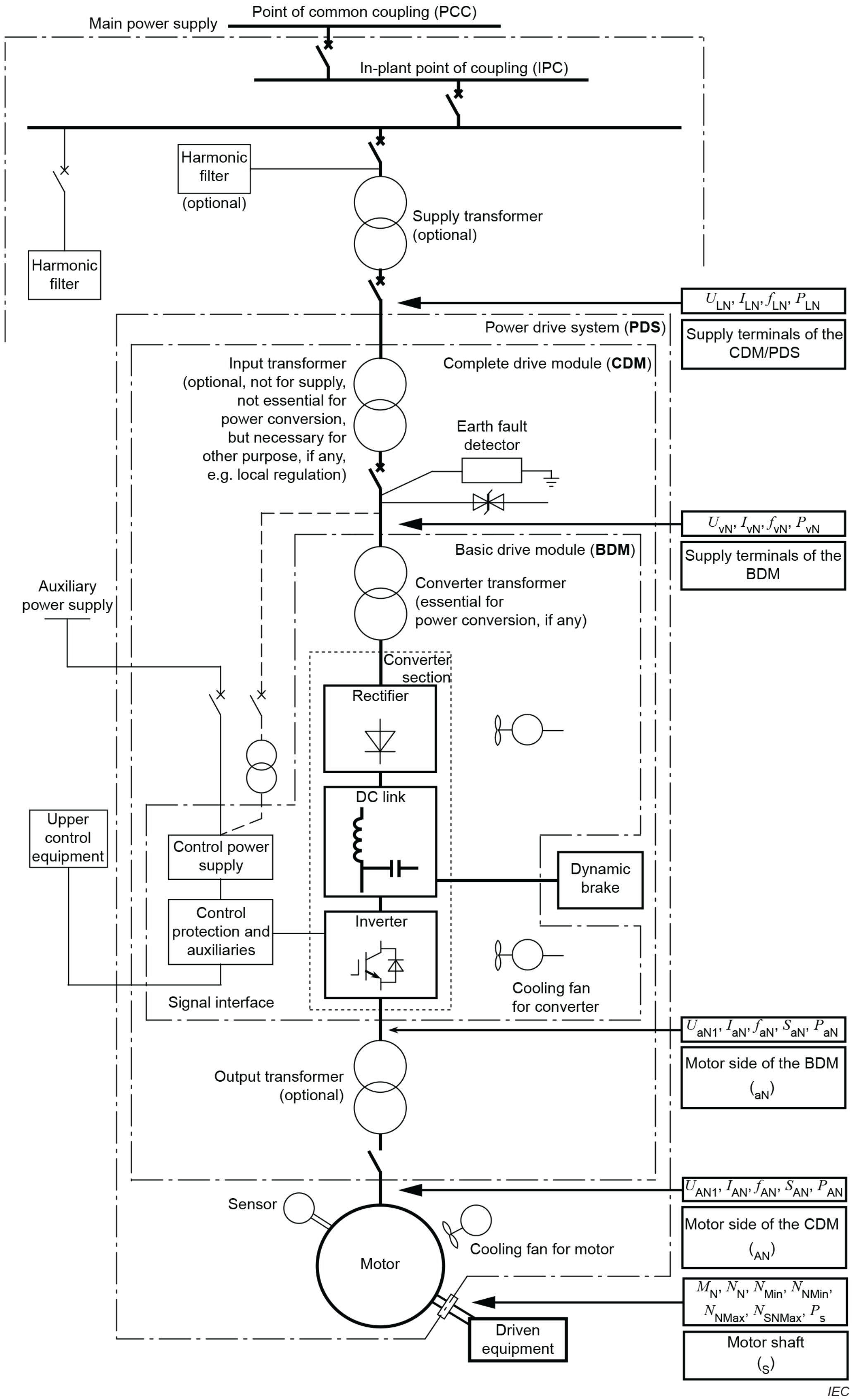


Figure 3 – Example of a *power drive system*

3.53
power factor
λ
under periodic conditions, ratio of the absolute value of the active power P to the apparent power S

$$\lambda = \frac{|P|}{S}$$

[SOURCE: IEC 60050-131:2002, 131-11-46, modified – The note to entry has been deleted.]

3.54
power interface
connections needed for the distribution of electrical power within the *PDS*

3.55
power port
port which connects the *PDS* to the power supply which also feeds other equipment

3.56
product packaging
temporary protection of the *BDM/CDM/PDS* or part of it during storage and known in-house transport routes

3.57
rated input active power
P_{vN}
<*BDM*> rated power determined by the fundamental components of voltage and current at the supply terminals of the *BDM*

3.58
rated input active power
P_{LN}
<*CDM/PDS*> rated power determined by the fundamental components of voltage and current at the supply terminals of the *CDM/PDS*

3.59
rated input apparent power
S_{vN}
<*BDM*> rated power determined by the RMS values of voltage and current at the supply terminals of the *BDM*

3.60
rated input apparent power
S_{LN}
<*CDM/PDS*> rated power determined by the RMS values of voltage and current at the supply terminals of the *CDM/PDS*

3.61
rated input current
I_{vN}
<*BDM*> maximum RMS value of current at the supply terminals of the *BDM* under rated conditions

Note 1 to entry: It takes into account rated load and the most onerous combination of all other conditions within their specified ranges, for example line voltage and frequency deviations.

3.62
rated input current
I_{LN}
<*CDM/PDS*> maximum RMS value of current at the supply terminals of the *CDM*/*PDS* under rated conditions

Note 1 to entry: It takes into account rated load and the most onerous combination of all other conditions within their specified ranges, for example line voltage and frequency deviations.

3.63
rated input frequency
f_{vN}
<*BDM*> rated value of the frequency at the supply terminals of the *BDM*

3.64
rated input frequency
f_{LN}
<*CDM/PDS*> rated value of the frequency at the supply terminals of the *CDM*/*PDS*

3.65
rated input voltage
U_{vN}
<*BDM*> RMS value of the rated input line-to-line voltage at the supply terminals of the *BDM*

3.66
rated input voltage
U_{LN}
<*CDM/PDS*> RMS value of the rated input line-to-line voltage at the supply terminals of the *CDM*/*PDS*

3.67
rated output active power
P_{aN}
<*BDM*> rated power determined by the fundamental components of voltage and current at the *motor* side of the *BDM*

3.68
rated output active power
P_{AN}
<*CDM*> rated power determined by the fundamental components of voltage and current at the *motor* side of the *CDM*

3.69
rated output apparent power
S_{aN}
<*BDM*> rated power determined by the RMS values of voltage and current at the *motor* side of the *BDM*

3.70
rated output apparent power
S_{AN}
<*CDM*> rated power determined by the RMS values of voltage and current at the *motor* side of the *CDM*

3.71
rated output current
I_{aN}
<*BDM*> maximum RMS value of the current at the *motor* side of the *BDM* which can be supplied continuously without exceeding established limitations, under rated operating conditions

3.72
rated output current
I_{AN}
<*CDM*> maximum RMS value of the current at the *motor* side of the *CDM* which can be supplied continuously without exceeding established limitations, under rated operating conditions

3.73
rated output frequency
f_{aN}
<*BDM*> range of fundamental frequency at the *motor* side of the *BDM*

3.74
rated output frequency
f_{AN}
<*CDM*> range of fundamental frequency at the *motor* side of the *CDM*

3.75
rated output power
P_{sN}
<*PDS*> rated (mechanical) power of the *PDS* determined by the *torque* and *speed* at the *motor* shaft

3.76
rated output voltage
U_{aN1}
<*BDM*> RMS value of the rated fundamental voltage at the *motor* side of the *BDM*

3.77
rated output voltage
U_{AN1}
<*CDM*> RMS value of the rated fundamental voltage at the *motor* side of the *CDM*

3.78
rated speed
N_N
<of a *motor*> maximum speed at which the *motor* is able to continuously deliver *rated torque* (M_N), at *rated* output *voltage* (U_{aN1}/U_{AN1}), *current* (I_{aN}/I_{AN}) and *frequency* (f_{aN}/f_{AN}) conditions

Note 1 to entry: See also Figure 10 and 5.3.3.2.

3.79
rated torque
M_N
<of a *motor*> *torque* the *motor* develops at its shaft end at *rated output power* and *speed*

[SOURCE: IEC 60050-411:1996, 411-48-05, modified – The symbol "M_N" has been added, as well as the word "power" and the domain.]

3.80
rectifier
<of the *BDM*> electric energy *converter* that changes single-phase or polyphase alternating electric currents to unidirectional current

See Figure 3.

[SOURCE: IEC 60050-151:2001, 151-13-45, modified – The domain and the reference to Figure 3 have been added.]

3.81
regeneration
process of converting the mechanical energy at the *motor* shaft of the *PDS* to electrical energy

3.82
resolution
minimum obtainable variation of the controlled variable

Note 1 to entry: It may be represented by an absolute value or a percentage of the maximum value.

3.83
responsible party
supplier, *manufacturer*, *OEM, system integrator, end user,* or *customer* of *BDM, CDM*, *electric motor*, *PDS*, driven equipment or extended product

3.84
routine test
test to which each individual device is subjected during or after manufacture to ascertain whether it complies with certain criteria

[SOURCE: IEC 60050-411:1996, 411-53-02, modified – The word "machine" has been replaced by "device".]

3.85
sample test
test on a number of devices taken at random from a batch

[SOURCE: IEC 60050-411:1996, 411-53-05, modified – The word "sampling" has been replaced by "sample" in the term. The word "machines" has been replaced by "devices".]

3.86
shipping packaging
temporary protection to prevent damage during worldwide air, sea and land transportation

Note 1 to entry: *Shipping packaging* can be realized as product specific transport packaging or as a *product packaging* with additional transport packaging.

3.87
short-circuit ratio
R_{SC}
ratio of the short-circuit power of the source at the point of common coupling (PCC) to the *rated apparent power* of the *BDM/CDM/PDS*

3.88
signal interface
input/output (I/O) connection for a line connecting the *basic drive module* or *complete drive module* (*BDM/CDM*) to another part of the *PDS*

3.89
special test
test in addition to *type test* and *routine test*, made either at the discretion of the *manufacturer* or according to an agreement between the *manufacturer* and the *customer* or customer representative

3.90
speed
N
<of a *motor*> rotational velocity of the *motor*

Note 1 to entry: See IEC 60050-811:1991, 811.13.03.

3.91
stimulus
change, variation or fluctuation of parameter which may cause deviation of performance or behaviour of the *PDS*

Note 1 to entry: Examples of *stimulus*: change of *speed* reference, load of *PDS*, *input voltage* or temperature.

3.92
system integrator
entity with responsibility to design the complete system of the application incorporating one or more *PDS*s

SEE Figure 1.

3.93
torque
M
<of a *motor*> twisting moment of force with respect to the longitudinal axis of the *motor* shaft

Note 1 to entry: This definition has been adapted from the note of IEC 60050-113:2011, 113.03.26.

3.94
total harmonic distortion
THD
ratio of the RMS value of the harmonic content of an alternating quantity to the RMS value of the fundamental component of the quantity

[SOURCE: IEC 60050-551:2001, 551-20-13, modified – The definition has been rephrased and the notes to entry removed.]

3.95
two quadrant operation
c*onverter* operation of a machine as a *motor* operation in either direction of machine rotation

Note 1 to entry: Two quadrant operation involves operation in quadrants I and III as shown in Figure 2.

3.96
type test
test of one or more devices made to a certain design to show that the design meets certain specifications

[SOURCE: IEC 60050-411:1996, 411-53-01, modified – The word "machines" has been replaced by "devices".]

3.97
witness test
tests performed in the presence of the *customer* or the representative of the *customer*

4 Guidance for specification of BDM/CDM/PDS and methodologies for compliance

4.1 General

This document provides a non-exhaustive list of requirements for performance, ratings or functionality to aid in the development of a functional specification between responsible parties. Each topic should be individually specified by the responsible party(ies) as a compliance requirement where appropriate for the intended application. When the *manufacturer* is the only *responsible party*, for any reason, the *manufacturer* may choose to select the specific sections of this document which are relevant for the intended application.

A list of performance, ratings and functionalities for consideration is provided in Table 6. This table contains all topics addressed by this document. The topics covered by this document and in the Performance/functionality requirement column may not be sufficient for the specific application under consideration and are provided as guidance. The columns for Responsible party and all suggestions underneath those headings are intended to encourage consideration of the related topics. They do not provide a definitive or exclusive answer of responsibility for a topic and are provided as guidance and not a rule. Absence of a suggestion under the Responsible party column does not imply the topic is never applicable, nor does the selection of a topic under the Responsible party imply it is applicable in all cases. The Subclause requirement/test specification columns are provided to link to the topics throughout the document, to provide guidance, but not to define absolute requirements. Information contained within the complete table is not intended to be exhaustive. There may be additional items of performance/rating/functionality, responsible parties, requirements and testing not defined within this document. If an application needs an additional requirement, it should be added to a working copy of this table as a new row; all information for this requirement shall be added, and then the requirement shall be addressed in accordance with 4.2.

4.2 Methodology for compliance

4.2.1 Agreement between *customer* and *manufacturer*

The *customer* is required to provide a detailed specification of the requirements of the application. This specification may or may not directly correlate with the contents of this document.

- A list of performance, ratings and functionalities for consideration is provided in Table 6. The *customer* and the *manufacturer* shall develop a list of requirements derived from Table 6 and other *customer* defined requirements appropriate for the application. This should be used as the basis for a contract. Consideration shall be given to the fact that the responsible parties may select some or all topics of this list as required by the application.
- The responsible parties may add supplementary requirements to this list if a mutual agreement is in place based on the requirement of the application.

In either case, it is the responsibility of the *manufacturer* to:

- define the test procedure, simulation, model, design specific solution, or other method used to create evidence that the means used is capable of proving the performance and/or functionality requirement of the item being validated in this manner;
- provide evidence of test, if required by the *customer*, proving the performance and/or functionality of the item.

All useful information should be made available by both parties.

NOTE This document makes no suggestion on how to build an agreement between the manufacturer and the customer.

4.2.2 Methodology to state compliance without *customer* input

The *manufacturer* is required to create a detailed specification of the requirements of the application.

A list of performance, ratings and functionalities for consideration is provided in Table 6. The *manufacturer* shall determine the required items from this list, based on the application requirements and *manufacturer*'s specifications. The resulting list shall become the basis of the statement of compliance. Consideration shall be given to the following:

- it is permissible to select some or all portions of this list as required by the application.
- it is permissible to add supplementary requirements to this list based on the requirement of the application.

In either case, it is the responsibility of the *manufacturer* to perform the following.

- Define the test procedure, simulation, model, design specific solution, or other method used to create evidence that the means used is capable of proving the performance and/or functionality requirement of the item being validated in this manner. There is no requirement to communicate this information.
- Maintain evidence of test, proving the performance and/or functionality of the item. There is no requirement to communicate this information.
- Provide detail of the functions and/or performance item in their product documentation. This is required to help customers in the selection of the product (see Clause 7).
- Produce evidence of test method and test execution upon request prior to purchase of equipment. The *manufacturer* is required to determine what information is required.

NOTE Evidence could be the selected list of application specific requirements created during the process, with verification of completion of each requirement, signed to validate that the requirements are met.

Table 6 – Selection of equipment rating, performance, functionality by responsible parties with corresponding test specification

	Responsible party													
Performance/ functionality requirement	**End user**	**Transformer supplier**	**Reactor supplier**	**Filter supplier**	**BDM supplier**	**CDM supplier**	***Motor* supplier**	**System integrator (PDS supplier)**	**Driven equipment supplier**	**Extended product supplier**	**Subclause requirement/ test specification**	**Type test**	**Routine test**	**Sample test**
Application specification	X				X	X		X			4.2.1; 4.2.2/ 6.1	X		
Visual inspection	X	X	X	X	X	X	X	X	X	X	6.6.1	X	X	X
Cooling system redundancy		X	X	X	X	X	X		X		5.2.4.1	X		
Air filtering		X	X	X	X	X	X		X		5.2.4.2	X		
Input ratings		X	X	X	X	X	X				5.3.2; 5.3.2.1 /6.6.3	X		
Input voltage		X	X	X	X	X	X				5.3.2.2 / 6.6.3.1	X		
Input frequency		X	X	X	X	X	X				5.3.2.2/ 6.6.3.1	X		
Input current		X	X	X	X	X	X				5.3.2.3 / 6.6.3.1	X		
Harmonic current					X	X	X	X			5.3.2.3 / 6.6.3.4.4	X		
Harmonic current HV (category 4)					X	X	X	X			5.3.2.3/ 6.6.3.4.4	X		
SCPD					X	X	X	X			5.3.2.4	X		
Output ratings		X	X	X	X	X	X	X			5.3.3 / 6.6.3.5	X		
BDM/CDM continuous output rating					X	X					5.3.3.1/ 6.6.3.1	X		
Harmonic current					X	X		X			5.3.3.1/ 6.6.3.1	X		
Harmonic voltage					X	X		X			5.3.3.1/ 6.6.3.1	X		
PDS continuous operation								X			5.3.3.2/ 6.6.3.1, 6.6.3.5.3	X		
Overcurrent								X			5.3.3.3/ 6.6.3.5.5	X		
Torque								X			5.3.3.3/ 6.6.3.5.3	X		
Overtorque								X			5.3.3.3/ 6.6.3.5.5	X		
Duty cycle derating	X								X	X	5.3.3.3/ 6.6.3.5.5	X		
Repetitive load duty	X								X	X	5.3.3.3/ 6.6.3.5.5	X		
Continuous duty	X								X	X	5.3.3.3/ 6.6.3.5.5	X		

	Responsible party													
Performance/ functionality requirement	**End user**	**Transformer supplier**	**Reactor supplier**	**Filter supplier**	**BDM supplier**	**CDM supplier**	***Motor* supplier**	**System integrator (PDS supplier)**	**Driven equipment supplier**	**Extended product supplier**	**Subclause requirement/ test specification**	**Type test**	**Routine test**	**Sample test**
Operating quadrants					X	X					5.3.4/ 6.6.3.5.6	X		
Operation in II and IV quadrant input and output ratings					X	X					5.3.4.2/ 6.6.3.5.6	X		
Control equipment rating					X	X		X	X	X	5.3.5 / 6.6.3.6	X		
Special ratings		X	X	X	X	X	X	X	X	X	5.3.6, 5.3.6.1; 6.6.3.7	X		
Special ratings transformer		X	X	X	X	X		X		X	5.3.6.2	X		
Transformer rating		X	X	X	X	X		X		X	5.3.6.2.1	X		
Core losses due to voltage harmonics		X	X	X	X	X		X		X	5.3.6.2.1	X		
Stray losses due to current		X	X	X	X	X		X		X	5.3.6.2.1	X		
Voltage waveform characteristics		X	X	X	X	X		X		X	5.3.6.2.1	X		
Compliance with product relevant standard		X	X	X							5.3.6.2.1	X		
Transformer load and overload ratings		X	X	X							5.3.6.2.1	X		
Harmonic voltage and current		X	X	X				X			5.3.6.2.3.1	X		
Transformer winding insulation stress		X	X	X				X			5.3.6.2.3.1	X		
Winding arrangement		X	X	X							5.3.6.2.3.2	X		
Phase offset requirements		X									5.3.6.2.3.3	X		
Rating plate requirements		X	X	X							5.3.6.2.3.4	X		
Ambient temperature		X	X	X							5.3.6.2.3.5	X		
Impedance		X	X	X							5.3.6.2.4.1	X		
Commutating reactance		X	X	X							5.3.6.2.4.2	X		
Impedance with self-commutated *converters*		X	X	X							5.3.6.2.4.3	X		
Common mode and DC voltages		X	X	X							5.3.6.2.5	X		
Cooling systems		X	X	X							5.3.6.2.6.1	X		
Voltage accuracy		X	X	X							5.3.6.2.6.2	X		
Parallel connection of bridges		X	X	X							5.3.6.2.6.3	X		
Shielding between primary and secondary wiring		X	X	X							5.3.6.2.6.4	X		
Short-circuit requirements		X	X	X							5.3.6.2.6.5	X		

	Responsible party													
Performance/ functionality requirement	**End user**	**Transformer supplier**	**Reactor supplier**	**Filter supplier**	**BDM supplier**	**CDM supplier**	***Motor* supplier**	**System integrator (PDS supplier)**	**Driven equipment supplier**	**Extended product supplier**	**Subclause requirement/ test specification**	**Type test**	**Routine test**	**Sample test**
Overvoltage limitation		X	X	X							5.3.6.2.7	X		
Special ratings – Motor							X	X		X	5.3.6.3	X		
Design requirements							X	X		X	5.3.6.3.2	X		
Performance requirements							X	X		X	5.3.6.3.3.1	X		
Input ratings							X	X		X	5.3.6.3.3.2	X		
Output ratings							X	X		X	5.3.6.3.3.1 5.3.6.3.3.3	X		
Protection against shaft voltage and current							X	X		X	5.3.6.3.4.1	X		
Vibration and lateral resonance							X	X		X	5.3.6.3.4.2/ 6.6.3.8.2	X		
Torque pulsations and torsion considerations							X	X		X	5.3.6.3.4.3	X		
Voltage stress of the *motor* winding insulation system							X	X		X	5.3.6.3.5.1, 5.3.6.3.5.2/ 6.6.3.8.5	X		
Functional evaluation of *motor* winding insulation systems							X	X		X	5.3.6.3.5.4	X		
Designation of essential data							X	X		X	5.3.6.3.6	X		
Bearing currents							X	X		X	5.3.6.3.7/ 6.6.3.8.4	X		
Performance											5.4	X		
Features					X	X	X	X		X	5.4.1.1	X		
Steady state performance					X	X	X	X		X	5.4.1.2.1/ 6.6.3.9	X		
Selection of deviation band					X	X	X	X		X	5.4.1.2.3	X		
Service deviation band – Limits					X	X	X	X		X	5.4.1.2.4	X		
Operating deviation band – Limits					X	X	X	X		X	5.4.1.2.5	X		
Dynamic performance					X	X	X	X		X	5.4.1.3.1/ 6.6.3.10.2; 6.6.3.10.3; 6.6.3.10.4; 6.6.3.10.5;	X		
Time response					X	X	X	X		X	5.4.1.3.2.1	X		
Response time					X	X	X	X		X	5.4.1.3.2.2	X		
Rise time					X	X	X	X		X	5.4.1.3.2.3	X		
Settling time					X	X	X	X		X	5.4.1.3.2.4	X		
Control bandwidth					X	X	X	X		X	5.4.1.3.3.2	X		
Dynamic braking					X	X	X	X		X	5.4.1.4	X		

	Responsible party													
Performance/ functionality requirement	**End user**	**Transformer supplier**	**Reactor supplier**	**Filter supplier**	**BDM supplier**	**CDM supplier**	***Motor* supplier**	**System integrator (PDS supplier)**	**Driven equipment supplier**	**Extended product supplier**	**Subclause requirement/ test specification**	**Type test**	**Routine test**	**Sample test**
Application requirements					X	X	X	X		X	5.4.1.5.1	X		
Supply connection requirements					X	X	X	X		X	5.4.1.5.2	X		
Rating requirements					X	X	X	X		X	5.4.1.5.3	X		
Fault supervision					X	X	X	X		X	5.4.2	X		
BDM/CDM/PDS protection interface					X	X	X	X		X	5.4.2	X		
Minimum status indication required					X	X	X	X		X	5.4.3	X		
I/O devices					X	X	X	X		X	5.4.4.1	X		
Process control interface/port					X	X	X	X		X	5.4.4.2.1	X		
Analog input					X	X	X	X		X	5.4.4.2.2	X		
Analog output					X	X	X	X		X	5.4.4.2.3	X		
Digital input					X	X	X	X		X	5.4.4.2.4	X		
Digital output					X	X	X	X		X	5.4.4.2.5	X		
Communication interface/ports					X	X	X	X		X	5.4.4.2.6	X		
Environmental impact					X	X	X	X		X	5.8.3	X		
Environ-mental condition for service, transport and storage		X	X	X	X	X	X	X	X	X	5.9.1	X		
Operation		X	X	X	X	X	X	X	X	X	5.9.2.1.1	X		
Mechanical installation service conditions and requirements		X	X	X	X	X	X	X	X	X	5.9.2.2.1	X		
Fixed *installations*		X	X	X	X	X	X	X	X	X	5.9.2.2.2	X		
Fixed *installations* as part of stationary machine		X	X	X	X	X	X	X	X	X	5.9.2.2.3	X		
Unusual environmental service conditions		X	X	X	X	X	X	X	X	X	5.9.2.3	X		
Sonic pressure and sound level		X	X	X	X	X	X		X		5.9.2.5 / 6.6.3.8.3	X		
Storage and transport of equipment		X	X	X	X	X	X		X		5.9.3	X		
Climatic conditions		X	X	X	X	X	X		X		5.9.3.1	X		
Unusual climatic conditions		X	X	X	X	X	X		X		5.9.3.2	X		
Ambient temperature		X	X	X	X	X	X		X		5.9.3.1	X		
Relative humidity		X	X	X	X	X	X		X		5.9.3.1	X		
Mechanical conditions		X	X	X	X	X	X		X		5.9.4	X		

	Responsible party													
Performance/ functionality requirement	**End user**	**Transformer supplier**	**Reactor supplier**	**Filter supplier**	**BDM supplier**	**CDM supplier**	***Motor* supplier**	**System integrator (PDS supplier)**	**Driven equipment supplier**	**Extended product supplier**	**Subclause requirement/ test specification**	**Type test**	**Routine test**	**Sample test**
Specific storage hazards		X	X	X	X	X	X		X		5.9.5	X		
Driven equipment interface					X	X	X	X	X	X	5.13	X		
Critical speeds					X	X	X	X	X	X	5.13.1	X		
Torsion analysis					X	X	X	X	X	X	5.13.2	X		
Explosive environment		X	X	X	X	X	X	X	X	X	5.14	X		
Bypass and redundant configurations		X	X	X	X	X	X	X		X	5.2.5	X		
Earthing requirements		X	X	X	X	X	X	X		X	5.15	X		

4.3 Applicable standards

This document makes many references to the following standards. These references are not intended to be exhaustive. These references are the best guidance of this document for the particular topic they are focussing on for the *BDM/CDM/PDS*. The user of this document is always responsible to determine the applicability of all of these standards to the product being considered, based on the intended application of the product.

- EMC requirements are covered by IEC 61800-3.
- General safety requirements are covered by IEC 61800-5-1.
- Functional safety requirements are covered by IEC 61800-5-2.
- Type of load duty guidance is covered by IEC TR 61800-6.
- Interface and use of profiles requirements are covered by IEC 61800-7 (all parts).
- *Power interface* voltage specification is covered by IEC TS 61800-8.
- Ecodesign energy *efficiency* requirements of drive system are covered by IEC 61800-9 (all parts).

5 Performance and functionality criteria

5.1 General

The detail in 5.3 to 5.15 provide a list of potential requirements relevant for the specification of a *BDM/CDM/PDS* based on what is selected from Table 6. More severe requirements might be specified if considered relevant for the application.

A *BDM/CDM/PDS* is typically designed for a specific application, in a specific environment, for use under specific conditions, in which the product needs to operate, be transported or stored. These conditions include, but are not limited to, the electrical, electro-magnetic, mechanical, climatic, thermal, and chemical environment as well as requirements on the functionality, safety and functional safety. These conditions are known by the *customer* or product standard committees using this document as a reference document and will need to be specified.

In order to ensure consistency and avoid conflicting requirements across IEC 61800 (all parts), some of the subclauses in 5.3 to 5.15 refer directly to other parts of the IEC 61800 series (see 4.3).

5.2 *BDM*/*CDM*/*PDS* characteristics and topology

5.2.1 General

Subclauses 5.2.2 and 5.2.3 are intended to be informative regarding common characteristics and topology for *PDS*s. The information in these subclauses shall not be understood as requirements.

Examples of commonly used drive system topologies are shown in Annex A.

5.2.2 *BDM/CDM/PDS* characteristics

AC *PDS*s are a type of electronic power conversion equipment which provide *speed*, current or *torque* control for AC electric *motor*s. Because AC induction *motor*s dominate industrial applications, AC *PDS*s designed to operate AC induction *motor*s are the most numerous. However, many high *efficiency motor* technologies already require a *CDM* for operation. Therefore, the use of AC *PDS*s with other types of AC *motor*s will continue to increase. The use of *CDM* with permanent magnet (PM) *motor*s has already reached a significant level.

Some significant characteristics of *BDM*/*CDM*/*PDS*s include the following.

- *BDM*/*CDM*/*PDS*s are commonly available with *output power* ranging from 0,2 kW to several thousand kW.
- Most industrial *BDM*/*CDM*/*PDS*s are designed to be powered from a 3 phase AC supply.
- Some low power *BDM*/*CDM*/*PDS*s are designed to be powered from single phase AC supply.
- Many *BDM*/*CDM*/*PDS*s are designed to receive DC power from a connecting *DC link power port* of more than one *PDS*. Many *PDS*s may receive power from both an AC and DC *mains supply.*
- *BDM*/*CDM*/*PDS*s vary the *speed* of an AC *motor* by controlling the frequency and voltage of the power provided to the *motor*.
- The most common *BDM*/*CDM*/*PDS*s are designed to control 3 phase induction *motor*s with voltage ratings such as 240 V, 400 V, 480 V, 600 V, and 690 V.
- Some *BDM*/*CDM*/*PDS*s are designed for use with stepper or switched reluctance *motor*s.
- Many *BDM/CDM/PDS*s are designed for use with permanent magnet *motor*s.
- The properly designed PDS or extended product can achieve improved energy *efficiency* from the very low power losses of the AC *BDM/CDM* when used at the correct operating points. In general, it is beneficial to reduce energy lost to heating effects in order to minimize size and operating cost.
- Most AC *PDS*s return electric power from the *motor* to the *DC link* during periods when the *motor* operates as a power generator (operation in quadrant II and *quadrant* IV).
- Some AC *PDS*s are provided with a dynamic brake (also called "chopper brake" or "brake chopper") in order to manage electric power returned from the *motor* to the *DC link* during periods when the *motor* operates as a power generator.
- Regenerative *PDS*s are designed to return power from the *DC link* of the *BDM*/*CDM*/*PDS*s to the AC supply.
- *BDM*/*CDM*/*PDS*s for use with AC induction *motor*s are available with different control algorithms which optimize *speed*/*torque* regulation and overall cost for different applications. Examples include:
  - volts/hertz control,
  - sensorless vector control,

– flux vector control,
– sensorless flux vector control,
– field oriented control,
– sensorless field-oriented control.

5.2.3 Basic topology for *BDM*/*CDM*/*PDS*s

The most commonly used topology for low-voltage *BDM*/*CDM*/*PDS*s is that of the voltage source *converter* (VSC). In a VSC, a supply-side c*onverter* changes electricity from the AC to DC. Capacitance is used to smooth the DC output of the *converter* and provide short-term energy storage. The DC output of the supply-side *converter*, sometimes referred to as the *DC link*, supplies energy to the *motor*-side *converter*, also known as an *inverter*. The *inverter* typically uses PWM (pulse width modulation) to provide the precise power requirements for an AC *motor* and permit control of *motor speed* and *torque*.

Figure 4 below illustrates a common *BDM*/*CDM*/*PDS*s topology. In Figure 4, energy flow is unidirectional from the AC power source into the *rectifier*. Energy flow between the *inverter* and *motor* is bidirectional depending upon the dynamics of the mechanical load on the *motor*.

The DC link port allows exchange of energy with the *DC link port* of other *BDM*/*CDM*/*PDS*s or with a dynamic brake. If the *DC link port* is connected to the *DC link* ports of other *PDS*s, it is possible to share energy either from the c*onverter*, or energy developed by the *motor* during operation in *quadrants* II and IV, with other *PDS* operating in *quadrants* I and III. Otherwise, the *DC link port* may be connected to an external dynamic brake in order to dissipate excess energy when the voltage of the *DC link* exceeds set limits. It is also possible to connect an external regenerative unit to the *DC link* and feed power back to the *mains supply*.

The *DC link* connection should be well designed and protected. In poorly designed *DC link* systems, it is possible for a low power *CDM* to feed a high power *CDM*. This may lead to destruction of the low power *CDM*. Also, if no suitable protection of the *DC link* connection has been provided, for example by fuses, fault conditions can lead to the destruction of one or more units connected to the common *DC link.*

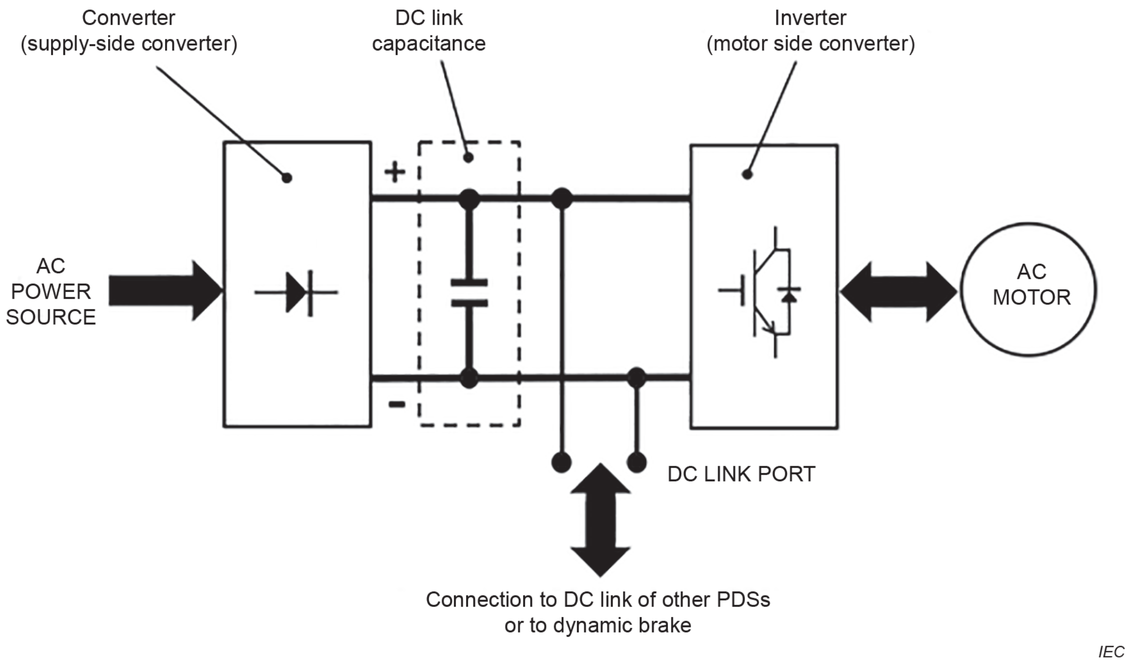


Figure 4 – Typical *BDM/CDM/PDS*

BDM/*CDM*/*PDS*s with common *DC link* ports can be constructed without a supply-side *converter*. These *PDS*s are intended for use together with other power conversion units. In these configurations, the *DC link port* becomes a means of energy exchange between the different units. Examples of these units include:

- *BDM*/*CDM*/*PDS*(s) with a *DC link port* (Figure 5);
- dedicated supply-side *converter*(s) (no figure);
- dedicated dynamic brake*(s)* (no figure).

A *PDS* with a *DC link port* is illustrated in Figure 5 below.

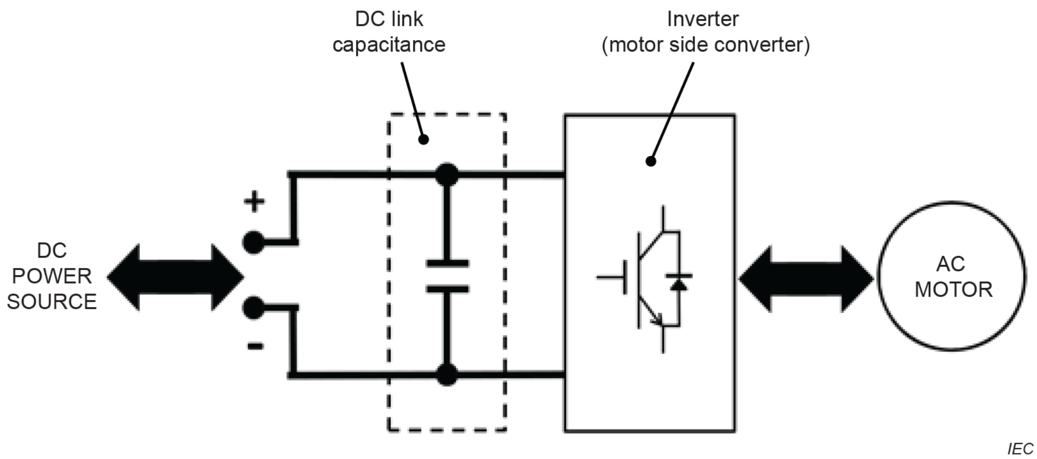


Figure 5 – Common *DC link* BDM/CDM/PDS

When a *BDM*/*CDM*/*PDS* operates in quadrants II and IV, the inertia of the *motor* and connected load, or sometimes potential energy in the connected load, results in energy being generated by the *motor* and returned through the *inverter* to the *DC link port*. During these periods, the energy returned to the *DC link port* is often managed using one or more of the following options:

- *BDM*/*CDM*/*PDS*(s) with *DC link* ports which use(s) energy available from the *DC link* to power other *motor*s;
- *dynamic braking* which dissipates excess energy from the *DC link* using resistors (Figure 6);
- return of energy in the *DC link* to an AC power system for use by other loads (see Figure 7).

Figure 6 illustrates a *BDM*/*CDM*/*PDS* which incorporates a dynamic brake. Dynamic brakes are also commonly available as stand-alone units for connection to a *DC link port*.

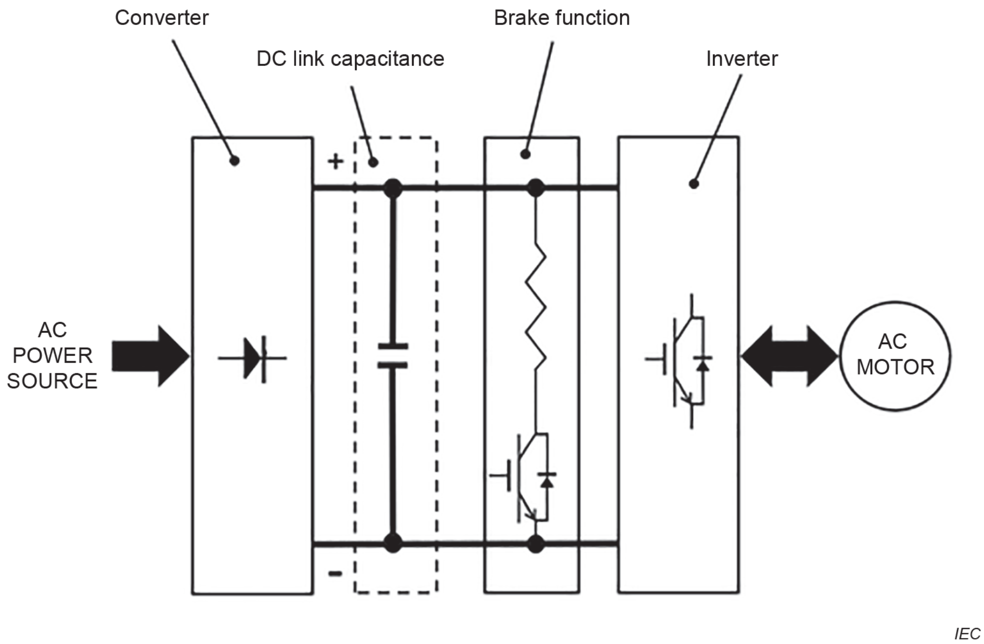


Figure 6 – *BDM/CDM/PDS* with brake

Figure 7 illustrates a regenerative *PDS* which can return energy to the *mains supply* using a supply-side *converter* which also can operate as an *inverter*, also known as *active infeed converters* (AICs) or as active front end *converter* (AFE).

Additional information regarding AIC and AFE are available in IEC TS 62578.

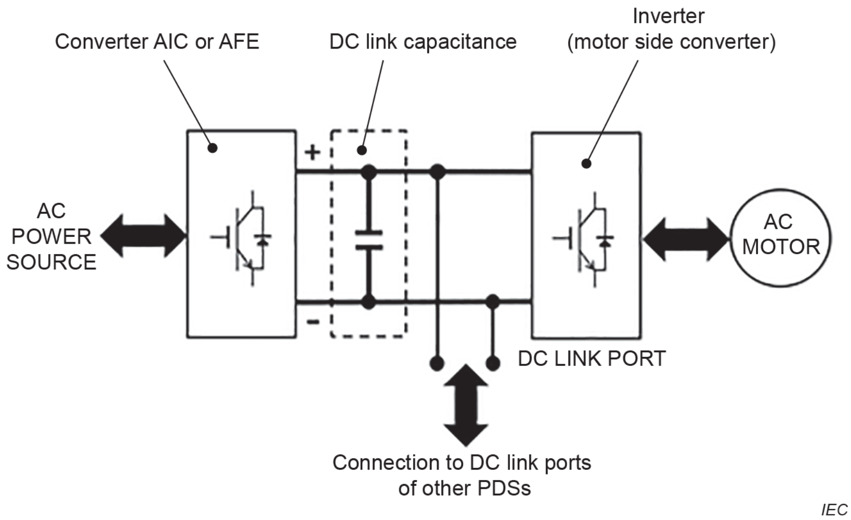


Figure 7 – *BDM/CDM/PDS* with AIC

5.2.4 Cooling topology

5.2.4.1 General

Common methods of cooling are forced air, liquid, heat exchangers, and evaporative cooling. Redundancy is recommended for critical applications.

Other cooling types are allowed.

Apply IEC 61800-5-1 for safety considerations.

5.2.4.2 Air-cooling

When the air supply has the potential to contain particles that could interrupt the *BDM/CDM/PDS* cooling paths, air filtering may be required to ensure the proper operation of an air-cooled system.

5.2.4.3 Liquid-cooling

When considering the proper operations of a liquid cooling system, the main considerations are monitoring and control of:

- conductivity,
- flow,
- condensation
- temperature,
- pressure, and
- maintenance of the system to prevent scale and corrosion.

Manufacturer should provide appropriate warnings and maintenance instructions for the cooling system. It is important to adhere to the assigned warnings and to *manufacturer*'s recommendations regarding intervals of cooling system maintenance. It is also important to ensure that the *BDM/CDM/PDS* is installed and operated in the environmental conditions for which it is designed.

Apply IEC 61800-5-1 for safety requirements.

5.2.4.4 Heat exchangers

This type of cooling system can either be configured air to air, air to liquid, liquid to air, or liquid to liquid. These terms define the method by which the heat is transferred (exchanged) out of the product where the cooling is required. Typical considerations for heat exchangers include those listed in 5.2.4.2 and 5.2.4.3. Special considerations should be given to the interface between the internal and external loop. This is especially true for an air to liquid or liquid to liquid heat exchangers. For air to liquid system, the concern is that liquid could enter into the air system through a leak. For the liquid to liquid system, the concern is that contaminated/conductive liquid could enter the inner loop from the outer loop.

Apply IEC 61800-5-1 for safety requirements.

5.2.4.5 Evaporative-cooling

This type of cooling is a special case of liquid cooling. This will typically involve having a portion of the cooling system inside and a portion outside. It is unlikely that this type of cooling system would be contained within the *BDM/CDM* and would likely be part of the PDS or even the extended system. Consideration should be given to overall size and expense of this method. This case is not specifically detailed in IEC 61800-5-1. The *manufacturer* would be responsible for the considerations required for the proper system operation.

5.2.5 Bypass and redundant configurations

BDM/CDM may have bypass and/or redundant configurations to satisfy different aims, among which are the following:

– normal changing from a *BDM/CDM* supply to a *mains supply* at the end of the system starting procedure;

– emergency switching from a *BDM/CDM* supply to a *mains supply*, in case of power *converter* failures, in such a way as to allow operation of the system at a fixed speed;
– maximum system availability and reliability, obtainable by including multiple power *converter* channels, acting as selectively separable subsystems – each of them allowing the operation of the system in case of partial failure, sometimes at reduced power, each drive subsystem acting therefore as an adjustable frequency bypass channel.

When bypass technology is used, it is important to consider if it is possible to start the motor directly from the *mains supply*.

Figure 8 shows an example of a bypass configuration for a PDS with indirect conversion: the bypass channel for the *BDM/CDM* may include a transformer for voltage level matching.

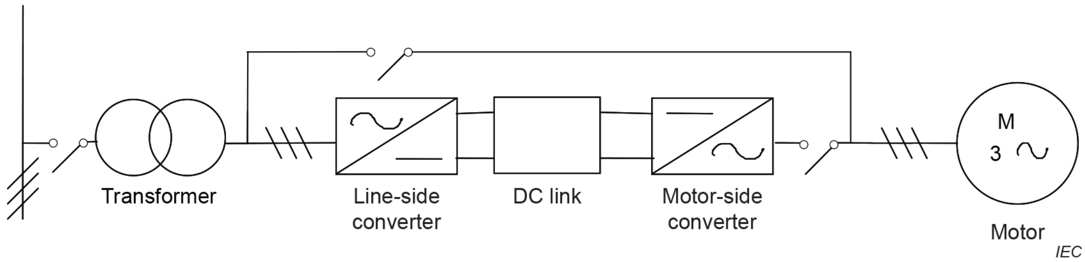


Figure 8 – Bypass configuration for system with indirect *converter*

An example of a redundant configuration is given in Figure 9.

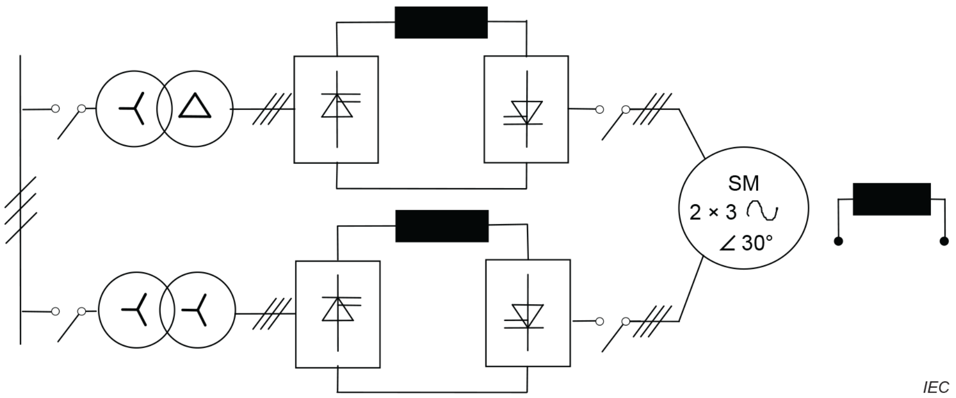


Figure 9 – Load commutation *inverters* LCI-synchronous *motor* in a partly redundant configuration

5.3 Ratings

5.3.1 General

The input and output ratings shown in Table 7 are acceptable for defining *BDM/CDM/PDS* proper operation.

When considering the safety requirements, apply IEC 61800-5-1.

For EMC considerations, apply IEC 61800-3.

For energy *efficiency*, apply IEC 61800-9-2.

Table 7 – Overview of input and output ratings of the *BDM/CDM/PDS*

Input ratings			Output ratings		
BDM	***CDM***	***PDS***	***BDM***	***CDM***	***PDS***
Voltage (U_{vN}) [V]	Voltage (U_{LN}) [V]	Voltage (U_{LN}) [V]	Voltage (U_{aN1}) [V]	Voltage (U_{AN1}) [V]	-----
Current (I_{vN}) [A]	Current (I_{LN}) [A]	Current (I_{LN}) [A]	Current (I_{aN}) [A]	Current (I_{AN}) [A]	*Torque* (M_N) [N·m]
Power (S_{vN} or P_{vN}) [kVA] or [kW]	Power (S_{LN} or P_{LN}) [kVA] or [kW]	Power (S_{LN} or P_{LN}) [kVA] or [kW]	Power (S_{aN} or P_{aN}) [kVA] or [kW]	Power (S_{AN} or P_{AN}) [kVA] or [kW]	Power (P_{sN}) [kW]
Frequency (f_{vN}) [Hz]	Frequency (f_{LN}) [Hz]	Frequency (f_{LN}) [Hz]	Frequency (f_{aN}) [Hz]	Frequency (f_{AN}) [Hz]	*Speed* (N_N and N_{NMax}) [r/min]

NOTE 1 In case no transformer nor other optional device such a filter is installed between supply mains input (i.e. *CDM*/*PDS* input) and *BDM* input, the ratings of *CDM*/*PDS* input and those of *BDM* input are same values, i.e. U_{vN} = U_{LN} and so on.

NOTE 2 In case no transformer nor other optional device such a filter is installed between *BDM* output and *motor* input (i.e. *CDM* output), the ratings of *CDM* output and those of *BDM* output are same values, i.e. U_{aN1} = U_{AN1} and so on.

NOTE 3 The *BDM/CDM output power* rating can be provided in either apparent power [kVA] or active power [kW]. Apparent power can be calculated using voltage and current.

NOTE 4 The *BDM/CDM/PDS* current, voltage and frequency ratings can be provided within a range of values.

5.3.2 Input ratings

5.3.2.1 General

The *system integrator* can consider whether the harmonic current, the harmonic voltage, and other input attributes of the *BDM/CDM* are important design considerations for the PDS.

5.3.2.2 *Input voltage* and *input frequency*

The rating(s) of the *BDM*/*CDM*/*PDS input voltage* and *input frequency* should be specified by the *manufacturer* to allow for proper selection of the *BDM/CDM/PDS*.

The rated *input voltage* is not adequate to determine that the supply is capable of sourcing the rated output load alone. The available current of the supply is important as well.

Standard voltage values are specified in IEC 60038. Different, non-standard voltage values may be specified for system optimization or special application needs.

For compliance, see 6.6.3.4.2.

5.3.2.3 *Input current*

The *BDM*/*CDM*/*PDS input current* rating should be specified by the *manufacturer* to allow for proper selection of the *BDM/CDM/PDS*. If multiple *input voltage* ratings or a range of voltages are specified in accordance with 5.3.2.2, the associated *input current* ratings should also be specified.

The specified *input current* includes the current required by the auxiliaries if they are supplied from the same source of the *BDM*/*CDM*/*PDS*.

The harmonic current spectrum of the PDS, considering from the fundamental to the 50th harmonic is possible. The first 25 harmonics have the greatest energy; therefore, they are the most significant. These harmonics can also affect the auxiliaries and should be considered (see 6.6.3.4.4).

If the *BDM/CDM/PDS* is a category C4 equipment as defined by IEC 61800-3, then harmonic current spectrum should be stated by the PDS *manufacturer* at the minimum specified AC line impedance (including the *BDM/CDM/PDS* supply transformer), and with no background supply-voltage distortion. For all other *BDM/CDM/PDS*, this requirement is covered by IEC 61800-3.

For compliance, see 6.6.3.4.3.

5.3.2.4 Short-circuit protective devices (SCPD)

A short-circuit protective device is likely required and should be considered. This device is specifically selected based on safety.

Apply IEC 61800-5-1 for definition and requirements.

5.3.3 Output ratings

5.3.3.1 *BDM*/*CDM* continuous operation

Continuous output operation of the *BDM*/*CDM* should be stated by the *manufacturer* and, if selected as a requirement, it shall be in terms of the *motor* requirements:

- fundamental AC voltage ($U_{\text{aN1}}/U_{\text{AN1}}$);
- *rated output current* ($I_{\text{aN}}/I_{\text{AN}}$);
- *output frequency* range;
- *rated maximum apparent output power* ($S_{\text{aN}}/S_{\text{AN}}$) [kVA] or maximum *output active power* ($P_{\text{aN}}/P_{\text{AN}}$) [kW].

If 5.3.3 is selected from Table 6, the operating frequency and voltage range shall be considered for the specified or typical output impedance. This would include all contributing impedances of the output like motor, transformer, filter, etc, if present or applicable.

NOTE Continuous, essentially equivalent to maximum steady state operation. See IEV 811-11-05.

The *system integrator* may wish to consider whether the harmonic current, the harmonic voltage, and other output attributes of the *BDM/CDM* are important design considerations for the PDS.

For compliance, see 6.6.3.5.2, 6.6.3.5.3, 6.6.3.5.4.

When CDM and *motor* are not provided by the same *manufacturer*/supplier, the *system integrator* should ensure proper performance and compatibility of CDM and *motor* as it pertains to operation for the specific system.

For safety, apply IEC 61800-5-1.

For EMC, apply IEC 61800-3.

For energy *efficiency*, apply IEC 61800-9-2.

5.3.3.2 *PDS* continuous output

Continuous output ratings should be stated by the *manufacturer*. If selected in Table 6, continuous output ratings shall be in terms of the *motor* shaft of the *PDS* (see Figure 10):

- *rated torque* (M_{N}) [N·m];
- *rated speed* (N_{N}) [r/min];
- *maximum rated speed* (N_{NMax}) [r/min];
- *minimum rated speed* (N_{NMin}) [r/min];
- *minimum speed* (N_{Min}) [r/min];
- *maximum rated safe speed* (N_{SNMax}) [r/min];
- *rated output power* (P_{sN}) [kW].

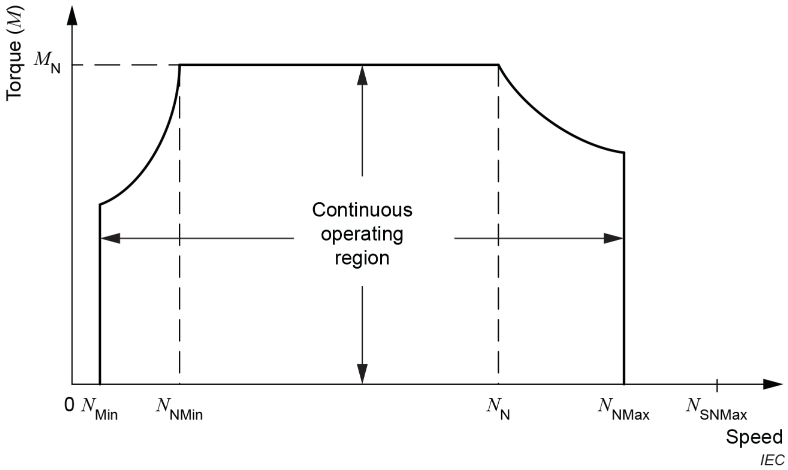


Figure 10 – Example of operating region of a PDS

For compliance, see 6.6.3.5.3, 6.6.3.5.4

5.3.3.3 Overcurrent and *torque* capability

Overcurrent, torque and overtorque should be considered when selecting a *BDM/CDM/PDS*. The defined minimum levels for safety listed as an overload requirement in IEC 61800-5-1 establish a range of acceptable overcurrent, *torque* and overtorque conditions. *Manufacturer*s typically create products that operate well within the maximum stated values in IEC 61800-5-1. Examples of typical overload magnitudes and duration are given in 5.10, IEC 60146-1-1 and IEC TR 61800-6. Non-typical overcurrent, *torque* and overtorque values are possible and the *customer* should consult the *manufacturer*'s product information for guidance on this topic to ensure the *BDM/CDM/PDS* meets the requirements of the application.

The performance of overload, *torque* and overtorque should be validated by test at the level the *manufacturer* specifies. These performance levels may be different than what is defined in IEC 61800-5-1 as long as they provide greater protection.

A good design rule for any type of duty cycle is that the RMS value of the current over the complete cycle should not exceed the rated current. Table 8 and Figure 11 show six typical examples of a 1 min overload with a 10 min and 60 min load cycle.

Table 8 – Example of reduced maximum continuous load as a function of an overload

Overload		Reduced continuous load	
Amplitude I_{aM} [p.u. of rated]	**Duration** T_{aM} [min]	**Maximum amplitude of** I_{aR} [p.u. of rated]	**Duration** T_{aR} [min]
1,5	1	0,928	9
1,5	1	0,989	59
1,25	1	0,968	9
1,25	1	0,995	59
1,1	1	0,988	9
1,1	1	0,998	59

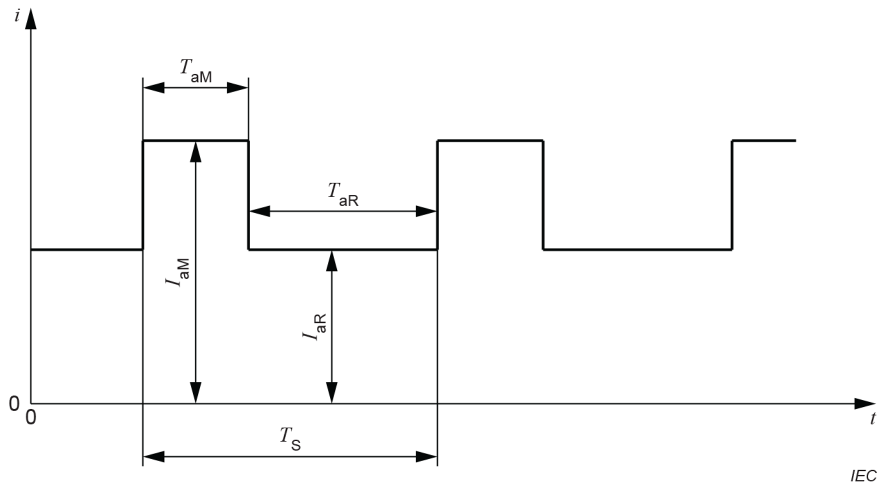


Figure 11 – Overload cycle example

For repetitive load duty, the *rated output current* (I_{aN}) should correspond, as a minimum, to the RMS value of the *motor* current for a full period of the *motor* duty cycle and the *output overload capability* of the *converter* should be adequate for the load duty cycle.

For continuous duty, the *rated output current* (I_{aN}) should correspond, as a minimum, to the continuous *motor* current necessary to supply the specified continuous *motor torque*.

For safety considerations of this topic, apply IEC 61800-5-1.

For testing options, see 6.6.3.5.5.

5.3.4 Operating *quadrants*

5.3.4.1 General

The above ratings of 5.3.2 and 5.3.3 should be given for all operating quadrants (I, II, III, IV) that are provided for operation of the *BDM/CDM*. Quadrants do not always require identical values/levels of performance.

5.3.4.2 Operation in II and IV quadrants

The operation in II and IV quadrant applies to applications when the *motor* is running as a generator, generating power back as explained in 5.2.

The input and output ratings under the operation in II and IV quadrants should be specified including the relevant parameters for the applicable solution.

For testing options, see 6.6.3.5.6.

5.3.5 Ratings and functionality of the control equipment

The ratings and functionality of the control equipment should be specified by the *manufacturer*.

For EMC related items, apply IEC 61800-3.

For safety related items, apply IEC 61800-5-1.

For functional safety related, apply IEC 61800-5-2.

For compliance, see 6.6.3.6.

5.3.6 Special ratings related to *BDM*/*CDM*/*PDS* or *motor*

5.3.6.1 General

Special ratings, performances or functionalities can be specified to provide further information for specific applications or considerations. This includes the effect on the *mains supply* side, inside the *BDM*/*CDM*/*PDS* as well as the effect on the *motor*. Any such special rating shall be specifically stated and detailed in the working copy of Table 6 and/or the agreement between responsible parties used to document compliance to this document, if selected as part of Clause 4.

5.3.6.2 Transformers and reactors

5.3.6.2.1 General

Power transformers may be used on the supply mains as well on the *motor* side of the *BDM*/*CDM*/*PDS* as step-up or step-down transformers. Transformers, whether internal or external to the *BDM* main enclosure, can also be part of the power conversion. An external transformer which is critical to the power conversion is part of the *BDM*.

The design should ensure compatibility between the transformer rating and the continuous input rating and overload capability of the *BDM/CDM/PDS* for functionality and performance.

For safety related topics, apply IEC 61800-5-1.

Additional core losses due to voltage harmonics, as well as additional stray losses due to the higher frequency current harmonics should also be considered, as appropriate for functionality and performance. Apply IEC 61800-9-2 for energy *efficiency* requirements.

Voltage waveform characteristics including insulation requirements should be considered. Transformers should comply with the product relevant standard for the particular type of transformer used as appropriate. IEC 60076 (all parts) and IEC 61378 (all parts) provide specifications for the design of these transformers; however, a nationally recognized product relevant standard would be acceptable.

NOTE In 5.3.6.2, where only transformers are mentioned, it means both transformers and reactors.

5.3.6.2.2 Transformers used in power conversion path

Subclause 5.3.6.2.2 addresses transformers in the power path of the *power drive system* (PDS) from input to conversion to output to load. Transformers can be used at the source (power system) end of the PDS or at the load (*motor*) end of the PDS. The purposes of transformers include:

– voltage matching;
– isolation;
– harmonic cancellation.
– rectification part of power conversion process (multiple secondary windings per phase).

Standard transformer construction types which are applied in PDS are dry-type and liquid-filled coil. The detail below is intended to assure the suitability of transformers for drive system duty as required.

The fundamental rating of the transformer should be appropriate for its intended application.

NOTE It is a good practice to have a transformer or reactor compliant to a nationally recognized product relevant standard if available.

Transformers supplied as part of the PDS should be properly rated to meet the requirements of:

– the steady state load;
– any momentary overloads.

For drive systems that normally run in adjustable speed mode, the transformer should be rated to deliver the required power on a steady state basis. Periodic overloads can be used to calculate an RMS apparent power (kVA) loading for the transformer.

The tests of IEC 60076 (all parts) and IEC 61378-1 may be relevant for *BDM/CDM/PDS* transformers.

5.3.6.2.3 Specification and rating

5.3.6.2.3.1 Harmonic currents and voltage

Converter modules cause harmonic currents and voltages, which cause an additional stress for the connected transformers (thermal, insulation). The transformer design should take special care of

– additional winding losses of each winding;
– additional iron core losses;
– additional insulation requirements (including common mode voltages and increased voltage stress).

In cases where the *converter* is sufficiently filtered on the valve side of the transformer, the use of standard transformers may be considered, assuming allowance is made for common mode voltages (insulation requirements).

Transformer windings should be defined according to the calculated insulation stresses (peak values, common mode, peak rise time, pulse frequency, reflections) defined by the drive system topology and the PDS power part earthing concept.

These values should be included in the transformer specification made by the PDS system integrator.

5.3.6.2.3.2 Winding arrangement

IEC 60076-1 contains the most common transformer winding arrangements and connection symbols.

Functionality and performance characteristics, (for example phase shift, winding arrangement, impedances) are important for the transformer design and *installation* purposes and should be properly considered.

5.3.6.2.3.3 Phase offset requirements

The harmonic attenuation effects to be achieved by multi-pulse transformer and *converter* circuits depend on the accuracy of the phase shift between the windings. The phase shift between the windings is specified at the fundamental frequency. Errors in the fundamental phase shift result in a much higher error at the harmonic frequency than at the fundamental frequency.

For example, a 2° error in phase shift for the fundamental of a 12 pulse PDS results in a phase error of (5 + 1) × 2° = 12° for the 5th and (7 – 1) × 2° = 12° for the 7th order harmonics. The corresponding residual values in case of a current source *converter* are:

$$\frac{I_5}{I_1} = \frac{1}{5} \times \sin\left(\frac{12°}{2}\right) = 0{,}021 \text{ and } \frac{I_7}{I_1} = \frac{1}{7} \times \sin\left(\frac{12°}{2}\right) = 0{,}015$$

For cancellation of higher harmonics, a 15° phase shift is used with extended delta or zigzag windings. In such cases, it is the 11th harmonic that is of most interest and a 2° phase error has a much higher impact.

The resulting phase error should be kept below 2° of fundamental period for a 12-pulse transformer, including phase error of the transformer windings and eventually the thyristor control system.

5.3.6.2.3.4 Rating plate requirements

IEC 60076-1 defines the requirements for rating plates and creates a comprehensive list of pertinent data to be listed on the rating plate of a transformer. Any nationally recognized product relevant standard provides a comparable list and would be acceptable. This information is readily available and should be used to ensure that the rating plate information that is selected is appropriate for the intended applications of the transformer.

5.3.6.2.3.5 Ambient temperature

The application need will determine the required ambient temperature range that the transformer will have to perform in. The application need should define the maximum and minimum temperature extremes the transformer would be subjected to. A transformer should be selected which is capable of meeting these requirements when it is continuously operated at its maximum load, or derating should be applied which forces the operation to stay within reduced parameters which are acceptable. This would meet the maximum temperature requirements.

For the specification of the minimum temperature of the *BDM/CDM/PDS*, the climatic and mechanical stress shall be considered, if selected as part of Clause 4. This includes

– the possibility of condensation when transitioning from an extremely cold state into operation, or
– the mechanical stress of a rapid temperature change on the materials used in the transformer.

Care should be taken to ensure that the transformer is selected appropriately for the range of ambient temperatures the application space will present.

In most cases, the supplier of the transformer will define the appropriate ambient temperature for the product in most conditions like storage, transportation, or operation. The selection of the transformer should consider and follow the *manufacturer*'s recommendations.

For safety, apply IEC 61800-5-1.

5.3.6.2.4 Impedance

5.3.6.2.4.1 General

The input transformer impedances should be coordinated in regard to harmonic emission and fault current requirements; typically, the impedance is in the 6 % to 12 % range according to IEC 60076 (all parts).

5.3.6.2.4.2 Commutating reactance

Commutating reactance is an important parameter for line commutated *converter*s. Measurement methods for commutating reactance are given IEC 61378-1.

5.3.6.2.4.3 Impedance with self-commutated *converter*s

Commutating reactance has less impact on the performance of self-commutated *converter*s. However, transformer impedance may be important to limit harmonic currents or fault currents. For self-commutated *converter*s, the impedance is usually taken to be the *short-circuit* transformer impedance measured in standard transformer tests. See IEC 60076-1. Measuring the *short-circuit* impedance at the frequency of interest may also be advisable.

5.3.6.2.5 Common mode and DC voltages

Some types of *converter*s can impose voltage offsets on input or output transformers. Two common problems caused by voltage offsets are:

– increased insulation stress due to common mode voltages or unusual voltage conditions;
– core saturation due to DC voltage or DC current magnetization.

These problems should be considered and addressed in the properly designed PDS.

Apply IEC TS 61800-8.

5.3.6.2.6 Specific considerations

5.3.6.2.6.1 Cooling systems

See IEC 60076-1.

5.3.6.2.6.2 Voltage accuracy

Apply IEC 60076 (all parts).

5.3.6.2.6.3 Parallel connection of bridges

Care should be taken when considering the case of parallel connection of bridges (accuracy of no-load voltages, phase shift, short-circuit impedance of each secondary winding).

5.3.6.2.6.4 Shielding between primary and secondary winding

An electrostatic shield is recommended in order to prevent high-voltage transients being transferred to the secondary due to capacitive coupling. The shield also has an EMC effect on the common mode impedance for conducted disturbances. For both reasons, the inductance of the shield connection to earth should be low.

For full EMC considerations, apply IEC 61800-3.

5.3.6.2.6.5 *Short-circuit* requirements

Existing *BDM/CDM* designs create an increased possibility of *short-circuit* events on the secondary of a transformer. This is due to the usage of power electronic circuits fed by the secondary of the transformer. These power electronic circuits are most likely to fail in a shorted condition at the start of the failure. Care should be taken to ensure that the transformer used is constructed to tolerate these occurrences, or additional protection should be provided to limit the energy to within acceptable levels during the *short-circuit* events.

5.3.6.2.7 Overvoltages

Additional overvoltage limitation may be required to be provided for main power supply transformers (for example transient energy absorption as lightning arresters (LA)). Care should be taken to ensure that it is addressed through construction or additional protection when required.

The energy of the non-repetitive transients caused by no-load switching of the main transformer feeding the *converter* assembly is related to the transformer magnetizing energy E. Under the assumption of a sinusoidal magnetizing current, the energy stored in the magnetizing impedance of the transformer can be calculated by the following equation:

$$E(J) = \frac{i_{\mathrm{mpu}}}{4 \times \pi \times f_{\mathrm{LN}}} \times S_{\mathrm{N}}$$

where

i_{mpu} is the magnetizing current, referred to the rated transformer current (p.u.);

f_{LN} is the rated frequency (Hz);

S_{N} is the apparent power of the transformer (VA).

5.3.6.3 *Motor*

5.3.6.3.1 General

It is important to ensure that the *motor* selected for the PDS is adequate for the intended application, including all modes of operations, environmental conditions, EMC, energy *efficiency*, and safety considerations. For operations and environmental conditions apply IEC 60034 (all parts), for EMC apply IEC 61800-3, for energy *efficiency* apply IEC 61800-9-2, and for safety apply IEC 61800-5-1. *Motor* construction can consist of general-purpose standard design as well as special application orientated. In addition to standard *motor* designs, new technologies including permanent magnet *motor*s and other special solutions are also considered.

In this field of application, many different types of *motor*s exist. Most are induction and synchronous *motor*s. The number of phases is typically three or six.

Requirements for commonly used *motor*s are covered by the relevant product standard of the IEC 60034 series. Subclause 5.3.6.3 considers the integration and interfacing of the *motor* as a part of the PDS.

5.3.6.3.2 Design considerations

Generally, the design of a *motor* should follow IEC 60034 (all parts) or nationally recognized equivalent.

Special attention is required because of the *speed* dependency on heat transfer of self-ventilated cooling systems and additional harmonic losses in *inverter* fed *motor* operation (see IEC 60034-25).

Unless otherwise specified, ambient and cooling temperatures, thermal class and temperature rise of the motor winding insulation system in *inverter* fed conditions should be in accordance with IEC 60034-1.

For *motor* energy *efficiency*, see IEC 60034-30 (all parts) and guidance from IEC 60034-1, for PDS energy *efficiency* IEC 61800-9-2, and for safety of the PDS see IEC 61800-5-1.

5.3.6.3.3 Performance requirements

5.3.6.3.3.1 General

The performance requirements of the motor should be selected to meet the requirements of the application. These requirements will commonly include voltage, current, frequency, speed, torque, inertia, environmental, etc.

In the case of 3-phase *motor*s, occasionally a direct bypass to the line-side of the *BDM/CDM* may be required. A *motor* partial-winding operation in the case of a winding system with a multiple of 3 phases is also conceivable.

If performance and rating conditions for such a bypass operation are required, this should be requested by the *customer* and have clear detail provided to the supplier. If selected, the following detail is provided, but not considered an exhaustive list.

– necessary starting performance;
– eventually different *rated torque*.

For additional performance information, apply IEC 60034 (all parts).

5.3.6.3.3.2 *Motor* input ratings

The parameters for the input to the *motor* fed from a *BDM/CDM* are important in the properly designed PDS. Information regarding *motor* rating, operating frequency and voltage ranges can be found in IEC TS 61800-8.

Additional important information is the *motor* current which should be considered at rated *motor* voltage, base *speed* and rated PDS load. The following information is likely required for all applications:

– the total RMS current of the *motor* (I_{AN});
– the fundamental and the relevant harmonic current spectrum of the *motor* may be required at the specified or typical output impedance (including *motor* and, if any, transformer and filters); the information specific to the *motor*, transformers and filters, if any.

The *system integrator* should consider the following when purchasing the *motor* to ensure it will work within the PDS design:

– the excitation current of the motor, if any;
– the auxiliary supply.

NOTE For detail on the additional losses due to the higher frequency current harmonics, see IEC 61800-9-2.

5.3.6.3.3.3 *Motor* output ratings

See 5.3.6.3.3.1.

5.3.6.3.4 Mechanical system integration requirements

5.3.6.3.4.1 Protection against destructive shaft voltages or bearing currents

The *system integrator* should determine whether a *motor* with bearing insulation at the non-driven end is required and supplied accordingly.

In addition to the recommended earthing practices, other preventive measures may be necessary. They are especially needed when high frequency components exist in the *motor* voltage, including common mode voltages, caused by the *converter*. Some additional insulation measures include:

– the complete isolation of the *motor* shaft from the motor frame by the insulation of all the *motor* bearings in combination with a suitable earthing of the shaft to exclude electrostatic charging effects;
– an insulated coupling used to connect the driven equipment.

Filtering can also be considered, according to the topology of the *inverter*, particularly in the case of PWM voltage source *inverter*s by means of:

– common mode filters;
– dv/dt limitation;
– sinusoidal filter.

The *system integrator* should give advice, if additional measures are required.

See IEC TS 61800-8 for guidance.

5.3.6.3.4.2 *Motor*-vibrations and lateral resonance

Unless otherwise specified, the permitted limits of vibration severity and method of measurement should be as defined in IEC 60034-14.

In this context, the correct *motor* fastening (foundation, mechanical string alignment and coupling) is a consideration of the *system integrator*, which will need to coordinate this with the *manufacturer* of the driven equipment and *motor*. Special attention should be given to the lateral resonance frequencies of the whole mechanical string.

For compliance, see 6.6.3.8.2.

5.3.6.3.4.3 *Torque* pulsations and torsion considerations

Torque pulsations are electromagnetically produced as a result of voltage and current harmonics in a *converter* fed *motor*.

Disturbing or dangerous influences on mechanical structure elements, such as excitation of torsion resonances of the *motor* and driven equipment, should be avoided during normal operation and under fault conditions.

Necessary analyses and corrective actions should be defined and managed by the *system integrator* and should be undertaken in close cooperation between *converter*, *motor* and driven equipment experts during the PDS and extended product design process.

For safety, apply IEC 61800-5-1, IEC 60034 (all parts), and other specific standards relating to the driven equipment as required.

5.3.6.3.5 Voltage stress of the *motor* winding insulation system

5.3.6.3.5.1 General

The *system integrator* should ensure that, in all practical conditions of operation, the voltage stress level does not exceed the insulation system voltage stress capability. Therefore, the *system integrator* is responsible for specifying the voltage stress level at the *motor* terminals, taking into account possible voltage reflection depending on the topology of the *converter*, cable type and length, etc. Relevant parameters for insulation stress are transient peak voltage values, peak rise time, repetition rate, etc.

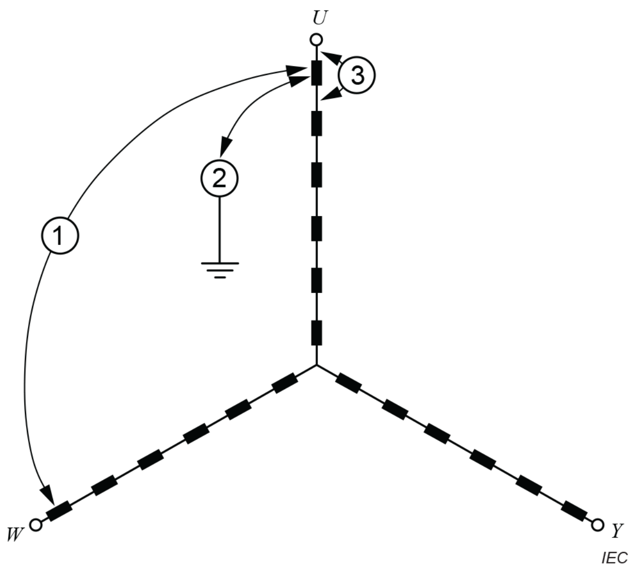
The *system integrator* should ensure that the *motor* selected will withstand the voltage stress of the application. To ensure that no service lifetime reduction of the *motor* insulation occurs, the actual stress due to *converter* operation should be lower than the repetitive voltage stress withstand capability of the motor winding insulation system.

For detail, see IEC 60034-25 and IEC TS 61800-8.

For testing options, see 6.6.3.8.5.

5.3.6.3.5.2 Types of winding stresses and limiting figures

Three different insulation stresses exist (see Figure 12).



Key

1 main insulation line to line

2 main insulation line to frame

3 inter-turn insulation in first coil

Figure 12 – Insulation stressing types

In line fed *motor*s (sinusoidal, low frequency), the most occurs in the line to line and line to frame insulation. The electric stress of the inter-turn insulation is relatively low; however, in the case of *converter* fed *motor*s, it can become very important and increased attention is necessary.

In a *converter* fed operation, the *motor* voltage is non-sinusoidal, typically with repeated transient voltage steps caused, for example, by fast switching PWM-inverters with relatively high pulse frequencies or by load side commutation notches of a thyristor *inverter*. In case of PWM voltage source *inverter* with motors fed via relatively long cables, each transient voltage step leads to reflections at the *motor* and the *converter* terminals with typically oscillating voltage overshoots (Figure 13).

t_a is the peak rise time of the voltage step (including the mentioned reflection phenomena). Definition of t_a is given in IEC 60034-25 as the time for the voltage to change from 10 % to 90 % of the total transient voltage Δu including overshoot (see Figure 13).

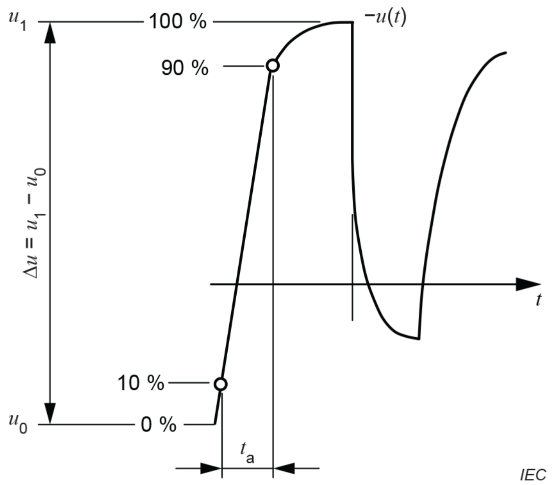
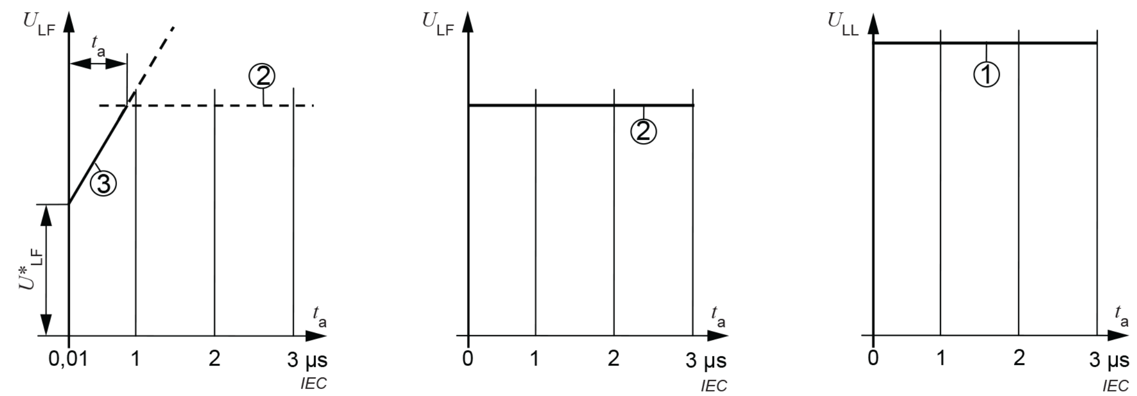


Figure 13 – Definition of the transient voltage at the terminals of the *motor*

The repetitive voltage stress withstand capability of the winding insulation system without service lifetime reduction can be described by the border lines given in Figure 14 a), Figure 14 b), and Figure 14 c). These borderlines refer to the admissible pulse voltage, including voltage reflections at the *motor* terminals. The numbers (circled 1, 2, 3 not on x-axis) in Figure 14 are common references to Figure 12 and to Table 9.



a) Determined by interturn insulation and winding design

b) Determined by main insulation line to frame

c) Determined by main insulation line to line

Figure 14 – Admissible pulse voltage (including voltage reflection and damping) at the *motor* terminals as a function of the peak rise time t_a

Figure 14 represents:

– inter-turn stressing type 3 relevant for transient voltage steps ΔU_{LF} with typical peak rise time $t_a \leq 1$ µs (Figure 14 a));

– voltage differences up to the withstand capability of the main insulation according to Figure 14 b) for line to frame stressing type 2;

–voltage differences up to the withstand capability of the main insulation according to Figure 14 c) for line to line stressing type 1.

5.3.6.3.5.3 Typical voltage stresses capability of *motor*s with usual design

Deriving from the insulation stress at line operation with usual voltage tolerances, the usual design of *motor*s gives at least a withstand capability indicated in the right column of Table 9. These formulae are given for guidance, if no further information is available from the *motor manufacturer* and represent minimum values. Significant higher voltage limitations are often proposed.

Table 9 – Limiting parts and typical voltage stress capability of the *motor* insulation system

Limiting part of insulation system	Relevant peak voltage value	Voltage stress capability of 3-phase motors
Main insulation, line to line, see ① from Figure 14	U_{LL} line to line voltage difference	$U_{LL} = 1{,}1\ U_{Ins}\sqrt{2} \approx 1{,}6\ U_{Ins}$
Main insulation, line to frame, see ② from Figure 14	U_{LF} line to frame max. voltage difference	$U_{LF} = 1{,}1\ U_{Ins}\ \sqrt{2/3} \approx 0{,}9\ U_{Ins}$
Inter-turn insulation of first coil, see ③ from Figure 14	$\Delta\ U_{LF}$ voltage step t_a associated peak rise time (see Figure 13)	ΔU_{LF} at least 3 kV $t_a \approx 1$ µs See Figure 14 a)
U_{Ins} is the rated RMS voltage value of *motor* insulation system.		

NOTE 1 The "rated voltage of insulation system" U_{Ins} (shown in Table 9) is not necessarily equal to the "rated *motor* voltage" U_{AN}.

NOTE 2 In the case of *inverter* fed *motor*s, it is often appropriate to use a *motor* design with improved insulation systems having $U_{Ins} > U_{AN}$ (*motor*) .

NOTE 3 As Figure 14 a) shows, the inter-turn insulation of the first coil is the limiting part for permissible transient voltage steps ΔU_{LF} in case of relatively short peak rise times in the range 0,01 µs ≤ t_a ≤ 1 µs.

For $t_a > 1$ µs, the relevant limitations are normally given by the main insulation (Figure 14 b) and Figure 14 c)).

NOTE 4 Because the switching of semiconductor elements in each phase occur at different times, the line to line voltage and the line to frame voltage have corresponding transient voltage steps $\Delta U_{LL} = \Delta U_{LF}$.

5.3.6.3.5.4 Functional evaluation of motor winding insulation systems

Test procedures for winding insulation systems used in *motor*s of rated voltage above 1 000 V should be in accordance with IEC 60034-18-31. Special attention is required, because of the additional stress factors produced by the *converter* fed operation such as increased voltage stress and high frequency repetition rate, additional heating as a result of harmonic losses and mechanical vibrations.

5.3.6.3.6 Designation of essential data

The following information may be of interest in addition to the normal rating plate of the motor:

- *rated torque*;
- *torque* at *minimum speed*;
- lowest *speed* at *rated torque*;
- *minimum speed*;
- base *speed*;
- maximum *speed*.

The following additional information may be necessary for a proper system design and installation of the motor, and may be supplied separately, for example in the product documentation:

- rotor moment of inertia and, if required, *motor* shaft stiffness for torsion investigations;
- additional *insulation* system data such as rated voltage;
- direction of rotation, and limit if any;
- air flow and surrounding requirements for *motor* cooling system;
- *motor* impedances (if required);
- relevant mounting dimensions;
- the shaft, the dimensions and the balancing should be in accordance with ISO/IEC, unless otherwise specified, "half key balancing" is relevant;
- mass of *motor* (rotor, stator);
- instructions for transportation, handling and storage;
- safety and maintenance instructions.

For detail, see IEC 60034 (all parts).

5.3.6.3.7 Bearing current

See IEC TS 61800-8 for detail.

For compliance, see 6.6.3.8.4.

5.4 Performance

5.4.1 Operational

5.4.1.1 General

The ratings of included features of the *BDM/CDM/PDS* should be specified by the appropriate *manufacturer*. One or more of the following features can be included (this list is not intended to be exhaustive):

- timed acceleration/deceleration;
- *dynamic braking*;
- reversing;
- *regeneration*;
- line filtering;
- input/output data processing (analog/digital);
- automatic restart;

- *DC braking.*

5.4.1.2 Steady state performance

5.4.1.2.1 General

The control system is in a steady state when the reference and operating variables have been constant for more than three times the settling time of the control system and the service variables have been constant for more than three times the longest time constant of the equipment (for example, the thermal time constant of the *speed* sensor). Steady state performance for drive variables such as *torque*, *speed*, position etc. should be considered in accordance with 5.4.1.2.2 to 5.4.1.2.5.

For compliance, see 6.6.3.9.

5.4.1.2.2 Deviation band

The deviation band (see Figure 15) is the total excursion of the directly controlled variable (unless another variable is specified) under steady state conditions as a result of changes in the service or operating conditions within their specified ranges.

The deviation band is expressed:

- as a percentage of the ideal maximum value of the directly controlled (or other specified) variable (see example in 5.4.1.2.3);
- as an absolute number for variables which have no readily definable base, such as position.

The signal representing the directly controlled variable should be filtered, for example by a first order low-pass filter with a 100 ms time constant, in order to remove noise and ripple from the signal.

NOTE The deviation band cannot be used to specify items which are not related with the steady state control performance (e.g. *torque* pulsation, or the *speed* ripple caused by load *torque* or *motor torque* pulsation).

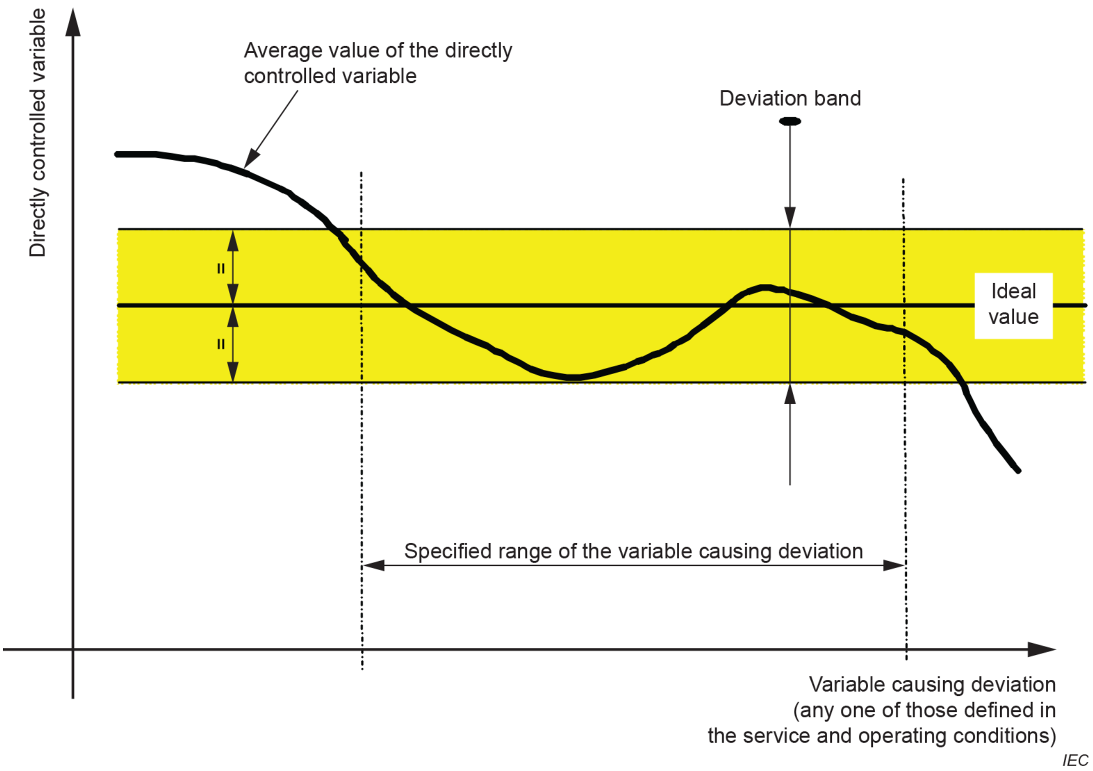


Figure 15 – Deviation band

5.4.1.2.3 Selection of deviation band

The steady state performance of a feedback control system can be described by a number, selected from Table 10, or a different level can be selected if appropriate for the application.

The range of variables to which the deviation band applies can be specified (see Figure 15).

Table 10 – Maximum deviation bands (percent)

±20	±10	±5	±2	±1	±0,5	±0,2	±0,1	±0,05	±0,02	±0,01

EXAMPLE A *PDS* has a 60 Hz; at 1 780 r/min *motor* that is fed by a frequency *converter*. The maximum *speed* of the *PDS* is 2 000 r/min and the specified deviation band for the speed control is ±0,5 %. Operating conditions are: *speed* range: 0 to 2 000 r/min; load *torque* range: zero to *rated torque*. Service conditions, ambient temperature range: 5 °C to 40 °C.

Thus, the deviation of the actual *speed* from the ideal value (speed reference) is:

±0,5 % of 2 000 r/min = ±10 r/min

when the value of the *speed* reference, load *torque* and ambient temperature are within their specified ranges.

For example, if the *speed* reference is 1 200 r/min, the actual *speed* of the *motor* will be 1 200 r/min ± 10 r/min, that is between 1 190 r/min and 1 210 r/min.

5.4.1.2.4 Service deviation band – Limits

The service deviation band specified by *BDM/CDM/PDS manufacturer*(s) should be followed under any combination of applicable service conditions at any time during any 1 h interval following a warm-up period, with the operating variables held constant during the observation.

5.4.1.2.5 Operating deviation band – Limits

The operating deviation band of the directly controlled variable should not be exceeded for the range of the operating variable indicated. The service conditions shall be held constant during the observation.

When required by the application, the performance information should also include data on the steady state relationship of the directly controlled variable to the reference. This aspect of performance is not included in the above discussion of operating or service deviation bands.

5.4.1.3 Dynamic performance

5.4.1.3.1 General

The dynamic performance of the *BDM/CDM/PDS* varies greatly based on application. There are many ways in which dynamic performance is achieved, including: current-limit, timed acceleration, inertia limits, ratio of voltage and frequency (V/Hz), etc. These parameters should be considered with respect to the final design of *PDS* and extended product with focus on the application need. For compliance, see 6.6.3.10.2, 6.6.3.10.3, 6.6.3.10.4, 6.6.3.10.5.

5.4.1.3.2 Time responses

5.4.1.3.2.1 General

Time response represents the output versus time curve resulting from the application of a specified input, under specified operating and service conditions.

The *PDS* should operate before the application of a specified input under the following operating and service conditions:

- base *speed*;
- *maximum rated speed*;
- no load;
- rated *input voltage* and *input frequency*;
- temperature stabilized after a 1 h warm-up of the measuring equipment and interfaces, ambient temperature being within service conditions.

The output curve may contain a significant amount of ripple, for example due to the operation of the power semiconductor devices in the *BDM*. The average curve should be used in the determination of the time response (see Figure 16). Typical time responses for a *PDS* are the time responses following a step change of *speed* reference, current reference or *torque* reference (see Figure 16) and the time response following a change in the load *torque* (see Figure 17). For specification purposes, the load *torque* of the driven equipment should be assumed to increase linearly from zero to a specified *torque* (or decrease from a specified *torque* to zero) within 100 ms, without overshoot.

5.4.1.3.2.2 Response time

The response time is the time required, following the initiation of a specified *stimulus* (in percentage of rise rate of change) to a system, for an output going in the direction of the necessary corrective action to first reach a specified value.

The specified value for a time response following a step change of reference input (see Figure 16) should be the initial average value plus 90 % of the steady state increment. The transient overshoot should be equal or less than 10 % of the steady state increment. For a time response following a change in an operating variable (see Figure 17), the specified value should be the final average value plus 10 % of the maximum transient deviation.

5.4.1.3.2.3 Rise time

The rise time is the time required for the output of a control system to make the change from a small specified percentage of the steady-state increment to a large specified percentage of the steady-state increment, either before overshoot or in the absence of overshoot (see Figure 16).

The small specified percentage should be 10 %, the large specified percentage should be 90 % and the transient overshoot should be equal or less than 10 % of the steady state increment. If the term "rise time" is unqualified, response to a step change is understood. Otherwise, the pattern and magnitude of the *stimulus* should be specified.

5.4.1.3.2.4 Settling time

The settling time is the time required, following the initiation of a specified *stimulus* to a system, for a specified variable to enter and remain within a specified narrow band centered on its final average value.

For a time response following a step change of reference input (see Figure 16), the specified band should be ±2 % of the steady state increment. For a time response following a change in an operating variable (see Figure 17), the specified band should be ±5 % of the maximum transient deviation.

5.4.1.3.2.5 Load impact *speed* deviation area

Load impact *speed* deviation area (corresponding to a drift of the position) provides an assessment of the response of a *speed* control for a sudden change in load *torque* (see Figure 17). The formula is

$$A = \frac{B \times C}{2} \quad (1)$$

where

A is the load impact speed deviation area;

B is the response time;

C is the transient deviation.

The maximum transient deviation is given as a percentage of the maximum operating *speed*. Thus, the unit of the load impact *speed* deviation area is percent seconds (% s).

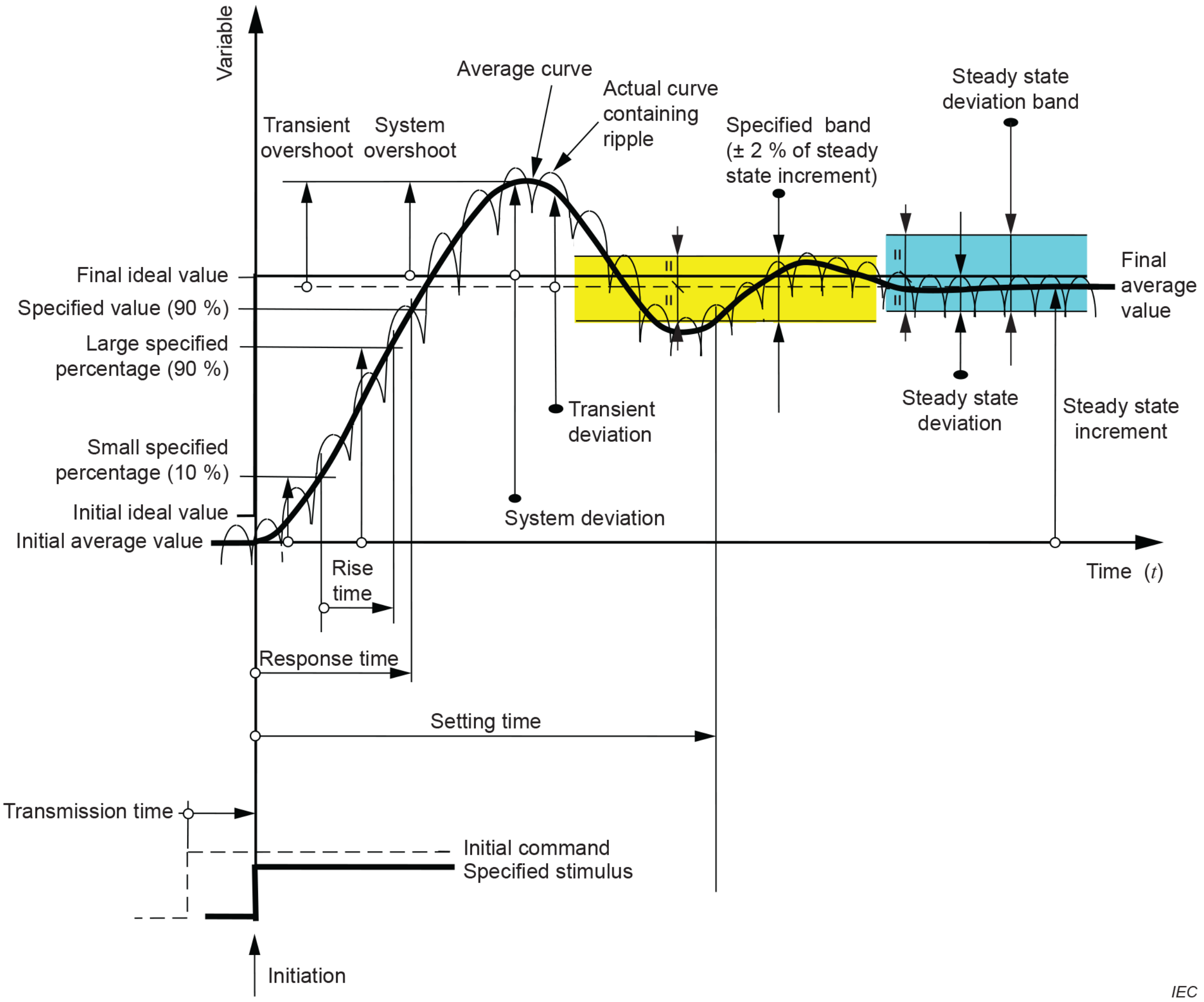


Figure 16 – Time response following a step change of reference input – No change in operating variables

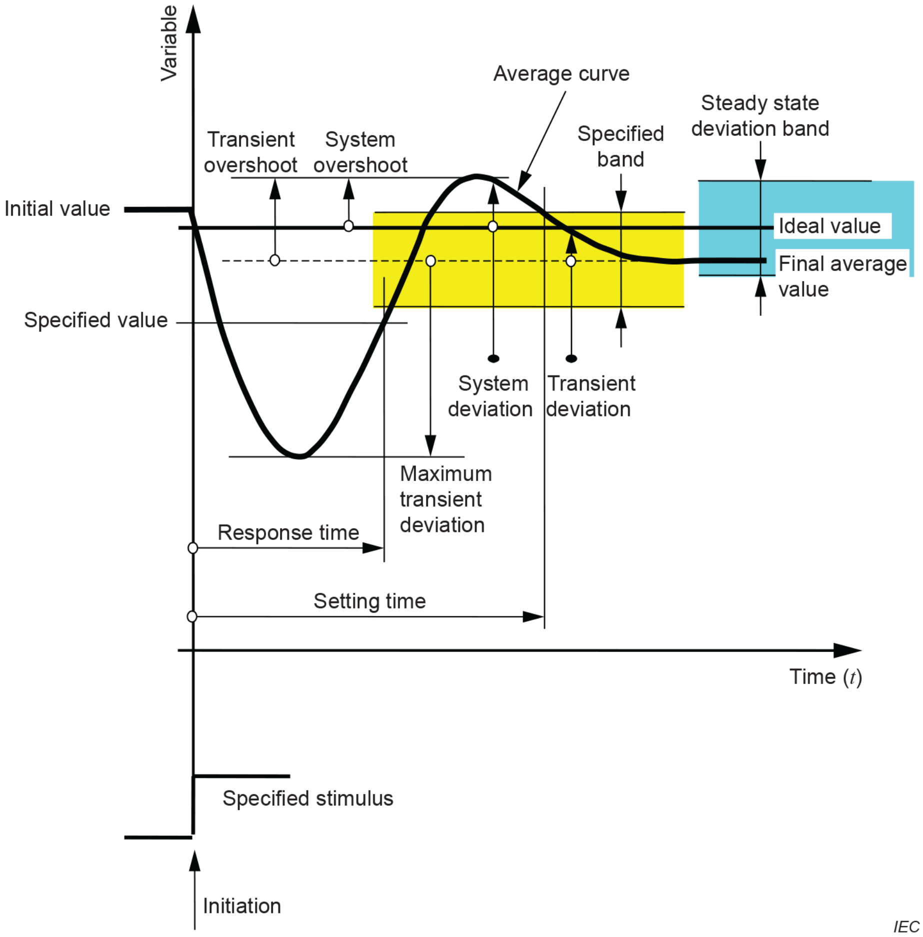


Figure 17 – Time response following a change in an operating variable – No reference change

5.4.1.3.2.6 Dynamic deviation

Dynamic deviation is the deviation between the reference (ideal value) and actual value when the reference is changed at specified rate (see Figure 18).

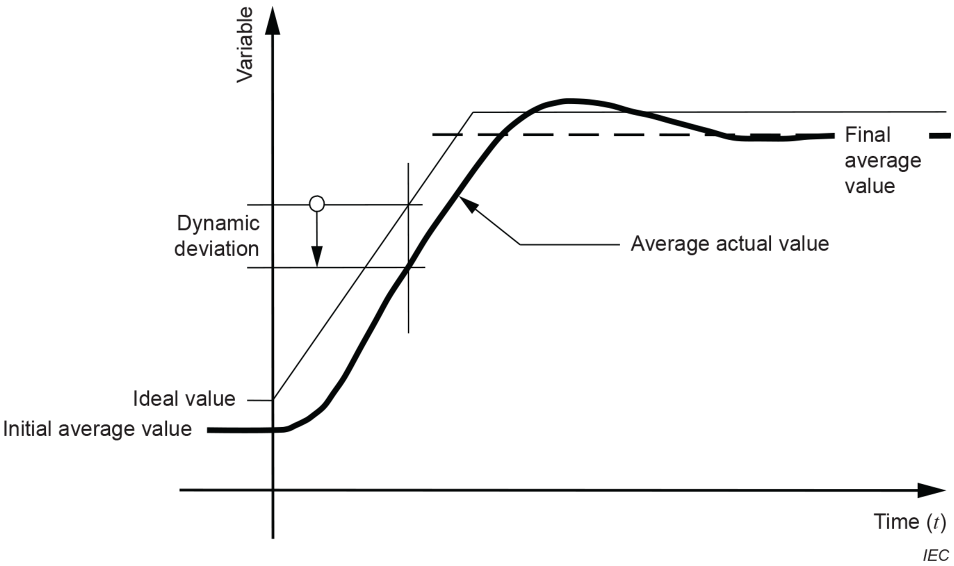


Figure 18 – Time response following a reference change at specified rate

5.4.1.3.2.7 *Torque* amplification factor (TAF)

Torque amplification factor is the ratio

$$A = \frac{M_p - M_{ini}}{M_{inc}} \tag{2}$$

where

A is the *torque* amplification factor;

M_p is the peak *torque* encountered in the shaft system after a sudden increase in the load *torque* by the amount M_{inc};

M_{ini} is the initial *torque* before the *torque* increase.

5.4.1.3.3 Frequency response of the control

5.4.1.3.3.1 Frequency analysis

Frequency response represents the amplitude ratio (amplification) and phase difference between the controlled variable and the sinusoidal *stimulus* as a function of the *stimulus* frequency when the feedback loop (if it exists) is closed.

NOTE 1 It is possible to use multi-frequency *stimulus* (noise) instead of the sinusoidal variable frequency *stimulus* when the frequency response is measured using a frequency analyzer.

NOTE 2 It is common to use decibels (dB) with the amplification (see IEC 60027-3). The formula is:

$$G = 20\log_{10}\left(\frac{F_2}{F_1}\right)\text{dB} \tag{3}$$

where

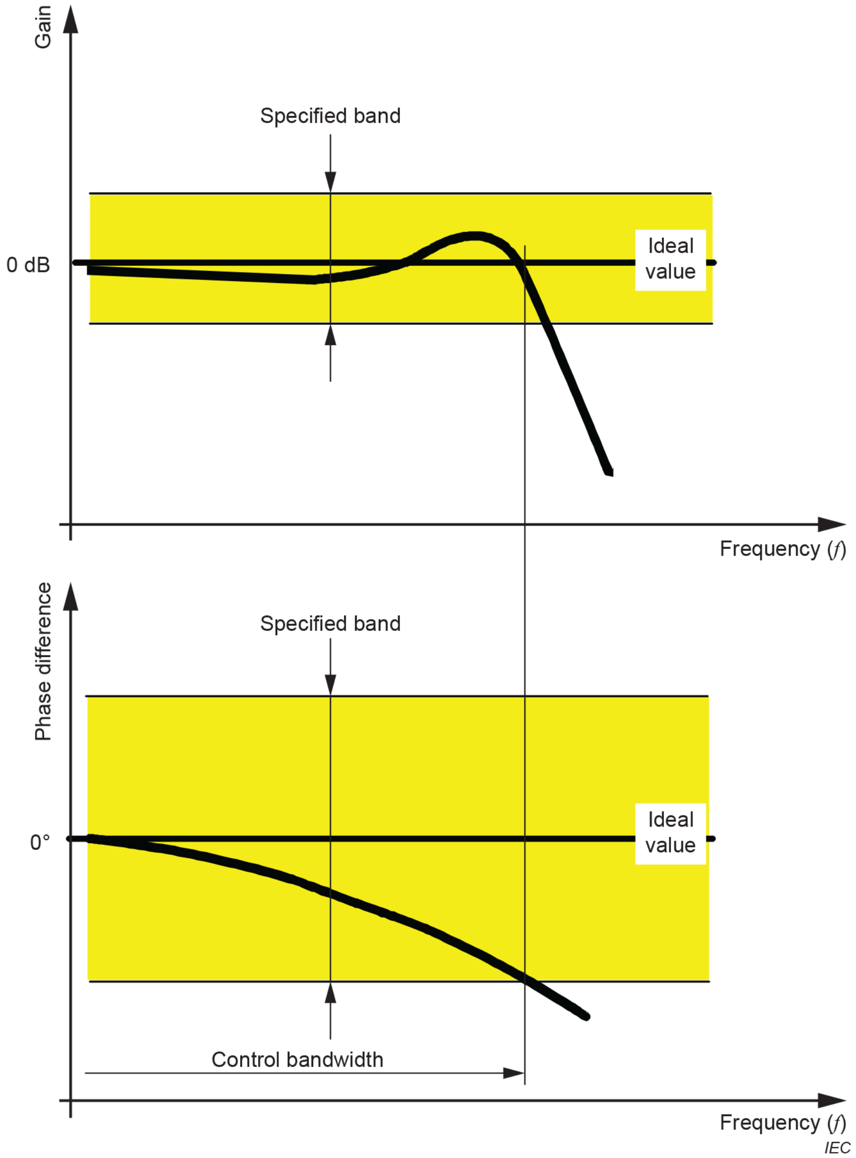
F_2/F_1 is the amplitude ratio;

G is the gain.

For example, if the amplitude ratio is 0,708, the gain is approximately –3 dB.

5.4.1.3.3.2 Control bandwidth

The control bandwidth is the frequency interval where both the amplification (gain) and phase difference of the frequency response with the reference variable as a *stimulus* remain within specified bands centered on 0 dB and 0° values, respectively (see Figure 19). The specified bands should be ±3 dB and ±90°.



NOTE The control bandwidth of the case shown in the figure is limited by the specified phase band.

Figure 19 – Frequency response of the control – Reference value as *stimulus*

5.4.1.3.3.3 Disturbance sensitivity

The disturbance sensitivity is the frequency response amplification when the *stimulus* is a specified operating variable. Typical example is the sensitivity of the *motor speed* for pulsating load torque.

NOTE The sensitivity can be expressed in dB only when both the controlled variable amplitude and the *stimulus* amplitude are expressed in per unit (p.u.).

5.4.1.4 Dynamic braking

5.4.1.4.1 Resistive braking

5.4.1.4.1.1 General

Resistive braking refers to the addition of dissipative elements (resistors) to allow faster electrical braking of the machine. Resistive braking here is considered to apply only to the use of a resistor across the *DC link* of *BDM/CDM/PDS*. This requires maintained control of the inverter. It is not necessarily the only or best method of emergency stopping.

5.4.1.4.1.2 Resistive braking (stop)

When resistive braking (stop) is provided:

a) the *converter* should be capable of braking a load at a current depending on *converter* rating;
b) *PDSs* with large variable inertia of the driven equipment (such as winders) should be capable of braking the maximum stored energy. With the *dynamic braking* resistor initially at ambient temperature, the energy rating should be adequate to allow stopping the drive system once from any operating speed. In this case, the inertia of the driven equipment should be provided by the *customer*.

5.4.1.4.1.3 Resistive braking (slowdown)

When resistive braking (slowdown) is provided:

a) the resistor should be capable of absorbing the total stored rotational energy of the *motor* and the driven equipment under specified braking sequences between specified speeds with the resistor initially at ambient temperature;
b) the *converter* should be capable of handling the AC current during the above sequence(s).
c) the inertia should be provided by the *customer.*

5.4.1.4.2 *DC braking*

DC braking can also be available.

NOTE The available braking *torque* can decrease at low speed.

5.4.1.4.3 Regenerative braking

Torque and *speed* can, in general, have two polarities, so that there are four quadrants of operation. If *torque* and *speed* have the same polarity, then power is flowing from the line to the *motor*. On the other hand, if the *torque* opposes the direction of rotation, then power is flowing from the *motor* to the line.

Energy transfer from the line to the *motor* is called "motoring operation", while energy transfer from the *motor* to the line is called "regenerating operation". Energy transfer from the *motor* to the line could include energy transfer to other devices connected to the *DC link* of the regenerating device.

Many of the topologies are capable of *four quadrant operation* and therefore, regenerative braking.

5.4.1.5 Other performance requirements

5.4.1.5.1 Application requirements

Application requirements may include:

- audible noise;
- operating quadrants: the usual combination are quadrants I, I and III, or all quadrants;
- *torque* as a function of *speed*;
- special mechanical conditions.

5.4.1.5.2 Supply connection requirements

Supply connection requirements may include:

- earthing;

- displacement factor at rated condition;
- line side harmonic content;
- maximum symmetrical fault current, *short circuit*.

NOTE For details, see IEC 61800-3 and IEC 61800-5-1.

5.4.1.5.3 Rating requirements

Rating requirements may include:

- *rated output current* (I_{aN}/I_{AN}) (see 5.3.3.1);
- *rated output voltage* (U_{aN1}/U_{AN1}) (see 5.3.3.1);

5.4.2 Fault supervision

5.4.2.1 General

The *BDM*/*CDM* should provide specified fault indication and response. This may consist of a common alarm and/or trip signal provided via dry relay contact(s) or static relay(s). The fault indication is normally activated by one or more of the *BDM*/*CDM* faults, which may include but are not limited to the following:

- external faults;
- *output power* section fault;
- instantaneous overcurrent;
- overtemperature (*converter*);
- loss of cooling air;
- *motor* overload;
- auxiliary power supply fault;
- supply overvoltage/undervoltage;
- loss of supply phase;
- internal control system fault;
- regulator/power circuit diagnostics;
- current limit or timed acceleration;
- overspeed and loss of *speed* feedback;
- cooling fan failure.

5.4.2.2 *BDM/CDM/PDS* protection interface

The *PDS* should contain the necessary protection functions, system components protection and generally high system availability. Well-designed protection will protect against contingencies internal and external to the drive system. This should include the protections listed in Table 11.

Table 11 – PDS protection functions

Line-side supply	Alarm	Trip	Remark
Outage, phase loss	X	X	
Line overvoltages	X	X	
Line under-voltages	X	X	
Line voltage unbalance	X	X	
Line feeder	**Alarm**	**Trip**	**Remark**
Overcurrent		X	
Overload	X	X	
Transformer	**Alarm**	**Trip**	**Remark**
Gas relay (Buchholz)	X	X	Oil-type only
Over-temperature	X	X	
Loss of cooling media	X	X	
Low oil level	X		Oil-type only
Converter	**Alarm**	**Trip**	**Remark**
Overcurrent	X	X	Commutation failure, *short circuit*, etc.
Overload	X	(X)	Thermal
Overvoltage	X	X	
Ground fault	X	(X)	
Loss of cooling	X	(X)	
Over-temperature	X	(X)	
Loss of auxiliary supply	X	X	
Loss of communication to process control	X	(X)	
Loss of *speed* feedback	X		
Motor	**Alarm**	**Trip**	**Remark**
Motor over/under-voltage	X	X	
Motor overcurrent	X	X	
Overload	X	(X)	Thermal
Over-speed	X	X	
Winding over-temperature	X	X	
Bearing over-temperature	X	X	
High vibrations	X	X	
Loss of cooling	X	(X)	
Loss of lubrication	X	X	
NOTE 1 Vibration protection functions can be taken care of by the driven equipment supplier. NOTE 2 (X): conditionally applied.			

The impedance of the supply network at the IPC, and the input impedances of the PDS shall be considered if selected as part of Table 6.

The demand for and the scope of the PDS protection system increase typically with the power of the drive system. For large or important drives, a diagnostic system to help the *customer* in fault conditions is recommended.

5.4.3 Minimum status indication required

The *BDM*/*CDM*/*PDS* should be equipped with a status indication signal for "drive on" (whether *motor* rotating or at standstill). The *BDM*/*CDM*/*PDS* may also be equipped with a status indication signal "drive ready for operation".

5.4.4 I/O devices

5.4.4.1 General

Number and nature of I/O should be stated by the *manufacturer*.

Inputs and outputs are needed for both variables and parameters. They are provided through analog or digital inputs/outputs using voltage or current. They are also communicated through serial or parallel links according to various communications standards. Both analog and digital variables can be manually set using a control panel and can be read on displays. Variables and parameters are treated in the same manner.

5.4.4.2 Process control interface/*port*

5.4.4.2.1 General

The process control interface/*port* and its performance should be defined. The following list can be used for the definitions.

5.4.4.2.2 Analog input

The items specified may include, but are not limited to, the following:

– number of analog inputs;
– type of analog input, for example:
  • single-ended voltage input,
  • differential voltage input,
  • current loop input;
– isolation voltage level of the input;
– *input voltage* or current range depending on the input type;
– input impedance;
– time constant or bandwidth of the hardware low-pass filter;
– gain and offset errors;
– *resolution* of the A/D converter;
– sampling interval of the A/D converter.

NOTE For a more complete list, see IEC 61131-2.

5.4.4.2.3 Analog output

The items specified may include, but are not limited to, the following:

– number of analog outputs;
– type of analog output, for example:
  • single-ended voltage output,
  • differential voltage output,
  • current loop output;

- isolation voltage level of the output;
- *output voltage* or current range depending on the output type;
- maximum load;
- time constant or bandwidth of the hardware low-pass filter;
- gain and offset errors;
- *resolution* of the D/A converter;
- conversion interval of the D/A converter.

NOTE For a more complete list, see IEC 61131-2.

5.4.4.2.4 Digital input

The items specified may include, but are not limited to, the following:

- number of digital inputs;
- type of digital input:
  - relay input,
  - opto-coupler input;
- isolation voltage level of the input;
- rated control voltage and type (AC or DC);
- input resistance;
- propagation delay of the input.

5.4.4.2.5 Digital output

The items specified may include, but are not limited to, the following:

- number of digital outputs;
- type of digital output, for example:
  - relay output of normally open contact,
  - relay output of normally closed contact,
  - transistor output of normally open contact;
- isolation voltage level of the output;
- maximum voltage and type (AC or DC);
- maximum current and type (AC or DC);
- operation delay of the output;
- propagation delay from input to output.

NOTE For a more complete list, see IEC 61131-2.

5.4.4.2.6 Communication interface/ports

The items specified may include, but are not limited to, the following:

- number of communication interfaces/ports;
- type of communication interface/*port*:
  - commissioning and maintenance interface/*port*,
  - automatic system interface;
- type of the physical interface/*port* (connector and cable type);
- protocol used;
- maximum data transfer rate in bits per second;

– maximum length of the cable that can be connected to the interface/*port*;
– maximum number of interfaces/ports that can be connected to the same communication cable or communication bus system.

5.5 General safety

For the approach to protection against hazards, apply IEC 61800-5-1. This document does not give any requirements for the safety evaluation of the *BDM*/*CDM*/*PDS* as this is covered by the products safety standard IEC 61800-5-1.

5.6 Functional safety

The product safety standard IEC 61800-5-2 provides requirements and guidance to prevent dangerous situations caused by failure in the *BDM*/*CDM*/*PDS* affecting motion.

Functional safety is also applicable when the *BDM*/*CDM*/*PDS* is used for applications in explosive atmosphere. See 5.14.

Examples of safety functions are:

- unexpected start-up,
- *speed*, *torque* or temperature exceeding the maximum permitted value.

This document does not give any requirements for the functional safety evaluation of the *BDM*/*CDM*/*PDS* as this is covered by the functional safety standard IEC 61800-5-2.

5.7 EMC

BDM/*CDM*/*PDS* are often installed in industrial environments which include both high power equipment and low-power electronic controls. EM (electro-magnetic) disturbances are prevalent in these environments on the AC main, on conductors used for communications and I/O between equipment and radiated through the air.

In other applications in commercial and residential environments, such as lifts, pumps, and HVAC (heating, ventilation, and air-conditioning), *BDM*/*CDM*/*PDS*s may operate in proximity to computers and consumer electronics. It is important that a *PDS* provide sufficient immunity to EM disturbances present in the application environment in order to operate properly and reliably. It is also important that a *BDM*/*CDM*/*PDS* does not generate EM disturbances which interfere with the proper operation of other equipment.

Requirements to ensure EM compatibility of *BDM*/*CDM*/*PDS* with different application environments are provided in IEC 61800-3.

IEC 61800-3 does not define EM immunity requirements for functional safety in *BDM*/*CDM*/*PDS*. Guidance for EM immunity in *BDM*/*CDM*/*PDS* associated with functional safety is provided in IEC 61800-5-2.

5.8 Ecodesign

5.8.1 General

The use of energy during the complete lifetime of the *BDM/CDM/PDS* including manufacturing, transportations, operation and disposal, as well as consideration about the selection, use and recycling of raw materials and substances may be taken into consideration.

5.8.2 Energy *efficiency* and power losses

Energy *efficiency* and/or power losses may be determined for the *BDM/CDM/PDS* itself. Energy *efficiency* of the application system (extended product approach) can be determined using IEC 61800-9-1. For the power losses determination for *CDM/PDS* classifications, power losses limits and measurement methodologies, apply IEC 61800-9-2.

5.8.3 Environmental impact

The *manufacturer* may provide environmental product declaration (EPD) information about the environmental impact, including the energy consumption during manufacturing, transportation and disposal of the *BDM*/*CDM*/*PDS*. The information concerning energy consumption should be based on a calculation including energy consumption used for manufacturing and transportation of individual components used in the *BDM*/*CDM*/*PDS*.

NOTE No IEC standard for *PDS* is available at the time of development of this document. EN 50598-3 is available as a reference document. UL 10001-1 is also available as a reference document.

5.9 Environmental condition for service, transport and storage

5.9.1 General

The product standard committee for the relevant part of the IEC 61800 series or the *manufacturer* should select the service conditions for operation according to the IEC 60721 series of standards. Attention should be paid to IEC 60721-3-0 which establishes guidance on the usage of the IEC 60721 (all parts). This guidance includes an explanation that the values set within are for reference and are not intended to take the place of the *manufacturer* determining the correct values for the usage of the product in its intended application. The values included in Table 12 and Table 13 and for storage and transportation according to 5.9.3 are acceptable for usage.

The environmental conditions in 5.9.2 to 5.9.6 could be considered minimum requirements, or the *manufacturer* will have to determine the correct levels required by the application. More severe conditions should be specified, if required by the application. See IEC 60721 (all parts) for detail and requirements.

5.9.2 Operation

5.9.2.1 Climatic conditions

5.9.2.1.1 General

The *manufacturer* should state the environmental service condition for the *BDM/CDM/PDS*. The values provided in Table 12 are for reference only. See IEC 60721 (all parts) for detail.

Table 12 – Environmental service conditions

Condition	Indoor conditioned IEC 60721-3-3:1994, IEC 60721-3-3:1994/ AMD1:1995 and IEC 60721-3-3:1994/AMD2:1996	Indoor unconditioned IEC 60721-3-3:1994, IEC 60721-3-3:1994/ AMD1:1995 and IEC 60721-3-3:1994/AMD2:1996	Outdoor unconditioned IEC 60721-3-4:1995 and IEC 60721-3-4:1995/ AMD1:1996
Climatic	Class 3K2 (Temperature: 15 °C to 30 °C) (Humidity: 10 % R.H to 75 % R.H./ non-condensing)	Class 3K3 (Temperature: 5 °C to 40 °C) (Humidity: 5 % R.H to 85 % R.H. / non-condensing)	Class 4K6 (Temperature: –20 °C to 55 °C) (Humidity: 4 % R.H to100 % R.H. / condensing) Rain, snow and hail are permitted.
Pollution degree	3 [b]	3 [b]	4 [c]
Overvoltage category according to IEC 60664-1	See IEC 61800-5-1		
Humidity condition of the human skin	Dry	Water wet [a]	Saltwater wet [a]
Chemically active substances	Class 3C1 (No salt mist)	Class 3C1 (No salt mist)	Class 4C2 (Salt mist) [a]
Mechanically active substances	Class 3S1 (No requirement)	Class 3S1 (No requirement)	Class 4S2 (Dust and sand)
Mechanical	Class 3M1 (Vibration: Table 14, Table 15) (Shock: Table 16)	Class 3M1 (Vibration: Table 14, Table 15) (Shock: Table 16)	Class 4M1 (Vibration: Table 14, Table 15) (Shock: Table 16)
Biological	Class 3B1 (No requirement)	Class 3B1 (No requirement)	Class 4B2 (Mould/fungus/ rodents/termites)
UV resistance	(No requirement)	(No requirement)	Yes [d]
The environmental conditions are guidelines. More severe conditions might be specified. Ultraviolet exposure (sun), food processing industry or other special applications. Marking in manual according to Clause 7. For testing, see Table 20.			

[a] Where it is ensured that the equipment will not be used in a salt mist atmosphere, water wet or saltwater wet condition, the *manufacturer* may choose to rate the equipment for a less severe condition. For information, see 7.3.

[b] Pollution degree 2 may be provided if the conditions in 5.9.2.1.2 are satisfied.

[c] Pollution degree 2 or 3 may be provided if the enclosure provides sufficient protection against conductive pollution and the conditions in 5.9.2.1.2 are satisfied.

[d] Material evaluated to be UV-resistant should be used for applications subjected to UV exposure

For an *integrated PDS,* the service conditions should comply with the most severe conditions from Table 12 or with those of the relevant standard for the *motor* from the IEC 60034 series.

The *BDM/CDM/PDS* IP rating should be in accordance with IEC 61800-5-1.

For compliance, see 6.6.8.3, 6.6.8.4, 6.6.8.5, 6.6.8.6, 6.6.8.7, 6.6.8.8, 6.6.8.9, 6.6.8.10, 6.6.8.11 relevant according to environmental condition specified by the *manufacturer*.

5.9.2.1.2 Pollution degree

Insulation between circuits is affected by pollution, which occurs during the expected lifetime of the *BDM*/*CDM*/*PDS*. The effect on the insulation might affect the performance of the *BDM*/*CDM*/*PDS* due to malfunctions.

Table 13 – Definitions of pollution degree

Pollution degree	Description
1	No pollution or only dry, non-conductive pollution occurs. The pollution has no influence.
2	Normally, only non-conductive pollution occurs. Occasionally, however, a temporary conductivity caused by condensation is to be expected.
3	Conductive pollution or dry non-conductive pollution occurs which becomes conductive due to condensation which is to be expected.
4	The pollution generates persistent conductivity caused, for example, by conductive dust or rain or snow.

Table 13 is provided for reference only. Apply IEC 61800-5-1 for requirements applicable to the selection of pollution degree.

5.9.2.2 Mechanical *installation* service conditions and requirements

5.9.2.2.1 General

Vibration, shock and free-fall conditions vary widely depending on the *installation* and environment and are very difficult to specify. For the purpose of this document, the service conditions are indirectly defined by the requirements in 5.9.2.2.2 and 5.9.2.2.3 for fixed installed *BDM/CDM/PDS*.

5.9.2.2.2 Fixed *installation*s

Fixed *installation*s of *BDM*/*CDM*/*PDS* should be placed on a rigid mounting surface which does not seriously interfere with the ventilation or cooling system.

Experience shows that equipment meeting the vibration test from 6.6.8.5 or the shock test from 6.6.8.6 is suitable for industrial use in fixed *installations*.

Vibration should remain within the limits of Table 14 which is considered normal for stationary equipment.

Table 14 – Environmental vibration limits for fixed *installation*

	IEC 60721-3-3:1994 and IEC 60721-3-4:1995 and IEC 60721-3-4:1995/AMD1:1996 3M1 and 4M1	
Frequency	**Amplitude**	**Acceleration**
Hz	mm	m/s^2
$9 \le f < 200$	Frequency dependent	1
NOTE The frequency range 2 Hz to 9 Hz covers earthquake, but not covered by this document. Earthquake can be specified. IEC 60721-2-6 provides more details.		

In addition to Table 14, PDSs with rated *converter input voltage*s above 1 000 V AC should remain within the limits of Table 15. Vibration beyond these limits and use on non-stationary equipment are considered unusual mechanical conditions.

Table 15 – *Installation* vibration limits

Frequency Hz	Amplitude mm	Acceleration m/s^2
$2 \leq f < 9$	0,3	Not applicable

The main transformer (if any) and the *motor* should comply with their applicable product standards (IEC 60076 (all parts) and IEC 60034 (all parts), respectively, or a nationally recognized equivalent standard).

Compliance is checked by test of 6.6.8.5 which is an accelerating test to demonstrate the ability of the *BDM/CDM* to withstand the mechanical stress during the estimated lifetime.

If shock needs to be considered, the values should remain within the limits of Table 16.

Table 16 – Environmental shock limits for fixed *installation*

Shock	IEC 60721-3-3:1994 and IEC 60721-3-4:1995 and IEC 60721-3-4:1995/AMD1:1996 3M1 and 4M1
Peak acceleration	40 m/s^2
Duration	22 ms

Compliance is checked by test with increased values of 6.6.8.6.

5.9.2.2.3 Fixed *installation*s as part of stationary machine

If the *BDM/CDM/PDS* is part of a stationary machine which creates vibrations and shock during operation, the mechanical stress can be higher than shown in Table 14, Table 15 and Table 16. If these values are known, the *manufacturer* should use them for testing.

The shock test is recommended if the *BDM/CDM/PDS* is part of a stationary machine.

If the mechanical stress exceeds the test values in 6.6.8.5 and 6.6.8.6, the values should be specified by the *customer,* and the *manufacturer* should use them for testing taking into account a margin.

5.9.2.3 Unusual environmental service conditions

The use of *BDM/CDM/PDS* under conditions exceeding the specified conditions listed in 5.9.2.1, and 5.9.2.2 shall be considered unusual.

Unusual service conditions may require special optional construction or protective features.

Examples to consider:

a) exposure to damaging fumes;
b) exposure to excessive moisture (relative humidity greater than specified);
c) exposure to excessive dust;
d) exposure to abrasive dust;
e) exposure to steam or water condensation;
f) exposure to oil vapour;

g) exposure to abnormal vibration, shock or tilting;

h) exposure to unusual transportation or storage conditions exceeding the values from Table 17;

i) exposure to extreme or sudden changes in temperature (exceeding 5 K/h);

j) unusual mounting space limitations;

k) cooling water containing acid or impurities which cause excessive scale, sludge, electrolysis or corrosion or obstruction, sea and hard water;

l) unusually high nuclear radiation;

m) altitude for thermal consideration, if rated for operation above 1 000 m;

n) altitude for insulation coordination if rated for operation above 2 000 m: see IEC 61800-5-1;

o) long periods not energized (days, weeks or months).;

p) severe restriction on audible noise;

q) exposure to explosive mixtures of dust or gases;

r) exposure to salt air;

s) outdoor equipment.

For unusual service conditions of the main transformer (if any) and *motor*, refer to the applicable product standards (IEC 60076 (all parts) or IEC 60076-11 and IEC 60034 (all parts), respectively).

5.9.2.4 The act of installing, commissioning and operation

The act of installing, commissioning, and operation have the same normal and unusual service conditions.

5.9.2.5 Sonic pressure and sound level

Equipment with the *BDM/CDM/PDS* has the potential for increased noise emissions based on a variety of reasons.

Air cooled equipment can have increased noise emissions due to the sound created by the fans and *motor*s cooling the equipment.

Transformers and reactors can have increased noise emission due to the sound created by non-sinusoidal currents.

*Motor*s can have increase noise emissions due to bearing wear and other mechanical friction.

Water cooled equipment can have increased noise emissions due to the *motor* and pump provided for cooling.

Regardless, these all have a weighted effect on the overall noise created by the system. This is an important consideration in system design for performance, functionality, and safety.

For safety associated with sonic pressure and sound level, apply IEC 61800-5-1 for *BDM/CDM/PDS*, IEC 60076-1 for transformers and IEC 60034-9 and IEC 60034-25 for *motors*.

The information associated with sonic pressure and sound level can be obtained from the *manufacturers* of the various equipment used to create the *PDS*. This then can be used to create an estimation of the effect this new equipment will have on the existing sound levels at the site of *installation*. However, the best result is to measure the sonic pressure and sound level after the equipment is installed to make a final determination on how to follow local laws and ensure the usage of the correct personal protective equipment PPE, if required.

For compliance, see 6.6.3.8.3.

5.9.3 Storage and transport of equipment

5.9.3.1 Climatic conditions

The *BDM/CDM/PDS* should be placed under adequate cover immediately upon receipt if packing coverings are not generally suitable for outdoor or unprotected storage. Table 17 is provided as a reference. For detail, see IEC 60721 (all parts).

Table 17 – Storage and transport limits

		Storage according to IEC 60721-3-1:1997 in product packaging up to 6 months	Transport according to IEC 60721-3-2:1997 in shipping packaging for more than 6 months
Climatic class		1K4	2K4
Ambient temperature [c]	**Min.**	−25 °C	−40 °C
	Max.	55 °C	70 °C
Biological environmental conditions		1B1 [a]	2B1 [a]
Chemically active environmental conditions		1C2	2C2
Maximum permitted temperature changes		0,5 K/min as average value over 5 min; equivalent to 30 K/h	Direct change in air/air: −40 °C to 30 °C at 95 %
Relative air humidity [d]		1K3 (5 % R.H to 95 % R.H.)	2K4 (5 % R.H to 95 % R.H.)
Rain		Not permitted	6 mm/min [b]
Water, but not rain		Not permitted	1 m/s and wet loading surfaces [b]
Air pressure	**Min.**	Above 70 kPa or below 3 000 m above sea level	
	Max.	Below 106 kPa or above sea level	
Condensation, spray water and ice		Permitted	
Salt spray		Permitted	
Solar radiation		1 120 W/m^2	
Vibration		1M2	2M3

[a] Mould, fungus, rodents, termites and other animal vermin not permitted.

[b] In sea- and weather-resistant *shipping packaging* (container).

[c] Temperature limits refer to the ambient temperature immediately surrounding the equipment (for example, inside a container).

Lower limits for the highest temperature are possible, provided a warning is given.

These limits apply with cooling liquid removed.

[d] Some combinations of temperature and humidity may cause condensation.

5.9.3.2 Unusual climatic conditions

Where transportation temperatures are below the *manufacturer*'s recommendation, the use of heated transport or the removal of selected low temperature sensitive components may be required.

5.9.4 Mechanical conditions

Equipment should be able to be transported, in the *product packaging* and *shipping packaging*, within the limits of IEC 60721-3-2:1997 class 2M1, or within limits specified by the *manufacturer*.

This includes the following: vibration in Table 18 and free fall in Table 19, or *manufacturer*'s specified limits.

Table 18 – Transportation vibration limits

Frequency Hz	**Amplitude** mm	**Acceleration** m/s^2
$2 \leq f < 9$	3,5	Frequency dependent
$9 \leq f < 200$	Frequency dependent	10
$200 \leq f < 500$	Frequency dependent	15

Table 19 – Transportation limits of free fall

Shipping weight with packaging kg	**Random free-fall drop height** mm		**Number of falls**
	IEC 60721-3-2:1997 (2M1)		
	With *product packaging*	**With *shipping packaging***	
$w < 20$	250		5
$20 \leq w < 100$	250		5
$w > 100$	100		5
NOTE More severe requirement can be found in IEC 60721-3-2:1997.			

If a free fall and vibration environment beyond those limits is anticipated, special packaging or transport is required.

If a less damaging environment is known to exist, packaging may reflect reduced requirements.

The main transformer (if any) and the *motor* should comply with their applicable product standards (IEC 60076 (all parts) or IEC 60076-11 and IEC 60034 (all parts), respectively, or a nationally recognized equivalent).

5.9.5 Specific storage hazards

The following require particular attention:

a) water – except for equipment specifically designed for outdoor *installation*: equipment should be protected from rain, snow, sleet, etc.;

b) condensation – sudden changes in temperature and humidity should be avoided;

c) corrosive materials – equipment should be protected from salt spray, hazardous gases, corrosive liquids, etc.;

d) time – the above specifications apply to shipping and storage with a total duration of up to six months; longer storage times may require special consideration (i.e. reduced ambient temperature range such as in class 1K3 of IEC 60721-3-1);

e) rodents and fungi – when storage conditions are likely to involve rodent or fungus attack, equipment specifications should include protective items:

   1) rodents – materials on the outside of the equipment and the size of apertures for cooling, connection, etc. should be specified such as to discourage rodent attack or entry;

   2) fungi – materials should be specified for a degree of fungus resistance suitable for the storage and operating environments.

5.9.6 Environmental service tests (*type test*)

Environmental service testing may be required to demonstrate the function of the *BDM*/*CDM*/*PDS* at the extremes of the environmental classification in Table 12 to which it will be subjected.

If size or power considerations prevent the performance of these tests on the complete *BDM*/*CDM*/*PDS*, it is permitted to test individual parts that are considered to be relevant to the function of the *BDM*/*CDM*/*PDS*.

When testing components or sub-assemblies separately, the temperature during the dry-heat test shall be chosen as to simulate actual use in the end-product. The component or sub-assembly shall be energized simulating the same conditions as in the end-product.

Table 20 shows the standard tests to be performed for the different environmental service conditions.

Product standard committees for the relevant parts of the IEC 61800 series or the *manufacturer* should select the relevant tests.

If selected, compliance is shown by conducting tests of 6.6.8.3 to 6.6.8.10 according to Table 20, as applicable for the environmental service conditions specified by the *manufacturer*.

Table 20 – Environmental service tests

Test condition	Indoor conditioned IEC 60721-3-3:1994	Indoor unconditioned IEC 60721-3-3:1994	Outdoor unconditioned IEC 60721-3-4:1995 and IEC 60721-3-4:1995/AMD1: 1996
Climatic	Temperature (see 6.6.8.3) Damp heat (see 6.6.8.4)	Temperature (see 6.6.8.3) Damp heat (see 6.6.8.4)	Temperature (see 6.6.8.3) Damp heat (see 6.6.8.4)
Chemically active substances	-	-	Salt mist [a] (see 6.6.8.7)
Water	-	Water test (see 6.6.8.10)	Water test (see 6.6.8.10)
Mechanically active substances	-	Dust (see 6.6.8.8)	Dust and sand (see 6.6.8.8, and 6.6.8.9)
Mechanical	Vibration (see 6.6.8.5) Shock (see 6.6.8.6)	Vibration (see 6.6.8.5) Shock (see 6.6.8.6)	Vibration (see 6.6.8.5) Shock (see 6.6.8.6)
Biological	-	-	-

[a] Where it is ensured that the equipment will not be used in a salt mist atmosphere, water wet or salt-water wet condition, the *manufacturer* may choose to rate the equipment for a less severe condition. For information, see 7.3.

When special environmental conditions are specified, additional tests (e.g. for chemically active substances) should be considered.

For *integrated PDS,* the test conditions should comply with the most severe tests from Table 20 or with those of the relevant standard for the *motor* from the IEC 60034 series.

5.10 Types of load duty profiles

The general performance features of the *CDM* are specified in 5.4, which covers the most common applications.

For special applications where other load profiles are requested, IEC TR 61800-6 provides further information about the current rating of the *CDM* for different kinds of load profiles covering equipment, assemblies and system aspects.

This included load profiles like:

- uniform load profiles,
- intermittent peak load profiles,
- intermittent load duty,
- intermittent load duty with no-load intervals,
- repetitive load duty,
- non-repetitive load duty.

IEC TR 61800-6 also specifies duty classes for non-repetitive industrial classes (IG to VG).

Compliance with special duty cycles according to IEC 60034-1 (S1 to S10) for rotating machines might be specified by the *manufacturer* following the guidance of IEC TR 61800-6.

5.11 Generic interface and use of profiles for *PDS*

BDM/*CDM*/*PDS*s used in industrial applications typically interface with one or more external control systems which coordinate operation of several *PDS*.

Often, the control system is separate from the drive and may consist of:

- one or more PLCs (programmable logic controllers), and/or
- a DCS (distributed control system), and/or
- a MES (manufacturing execution system).

NOTE 1 The control system software can be partially or entirely embedded in the *BDM/CDM/PDS*.

IEC 61800-7 (all parts) define a means to access functions and data in a *BDM*/*CDM*/*PDS* by providing a series of well-defined communication profiles and interfaces. The objective is a common drive model with generic functions and objects suitable to be mapped into different communication interfaces/ports.

From the perspective of control software, the communication and control functions of a *BDM*/*CDM*/*PDS* may be characterized by profiles. A *BDM*/*CDM*/*PDS* device profile is a representation of the parameters and behaviour of the *BDM*/*CDM*/*PDS* which may be used to facilitate control of the *BDM*/*CDM*/*PDS*. This device profile can then be mapped onto different network technologies (e.g. "communication profiles" of the IEC 61158 fieldbus series) to facilitate control of a *BDM*/*CDM*/*PDS* over a network.

IEC 61800-7 (all parts) defines a generic interface and profiles for *BDM*/*CDM*/*PDS* to be used with a control system and consists of the following parts:

- IEC 61800-7-1 defines requirements for a generic interface with the control software;
- the series IEC 61800-7-2xx specifies different drive profiles;
- the series IEC 61800-7-3xx specifies mappings of the device profiles onto various network technologies.

The relationship of IEC 61800-7 (all parts) to control system software and the *BDM*/*CDM*/*PDS* is represented in Figure 20.

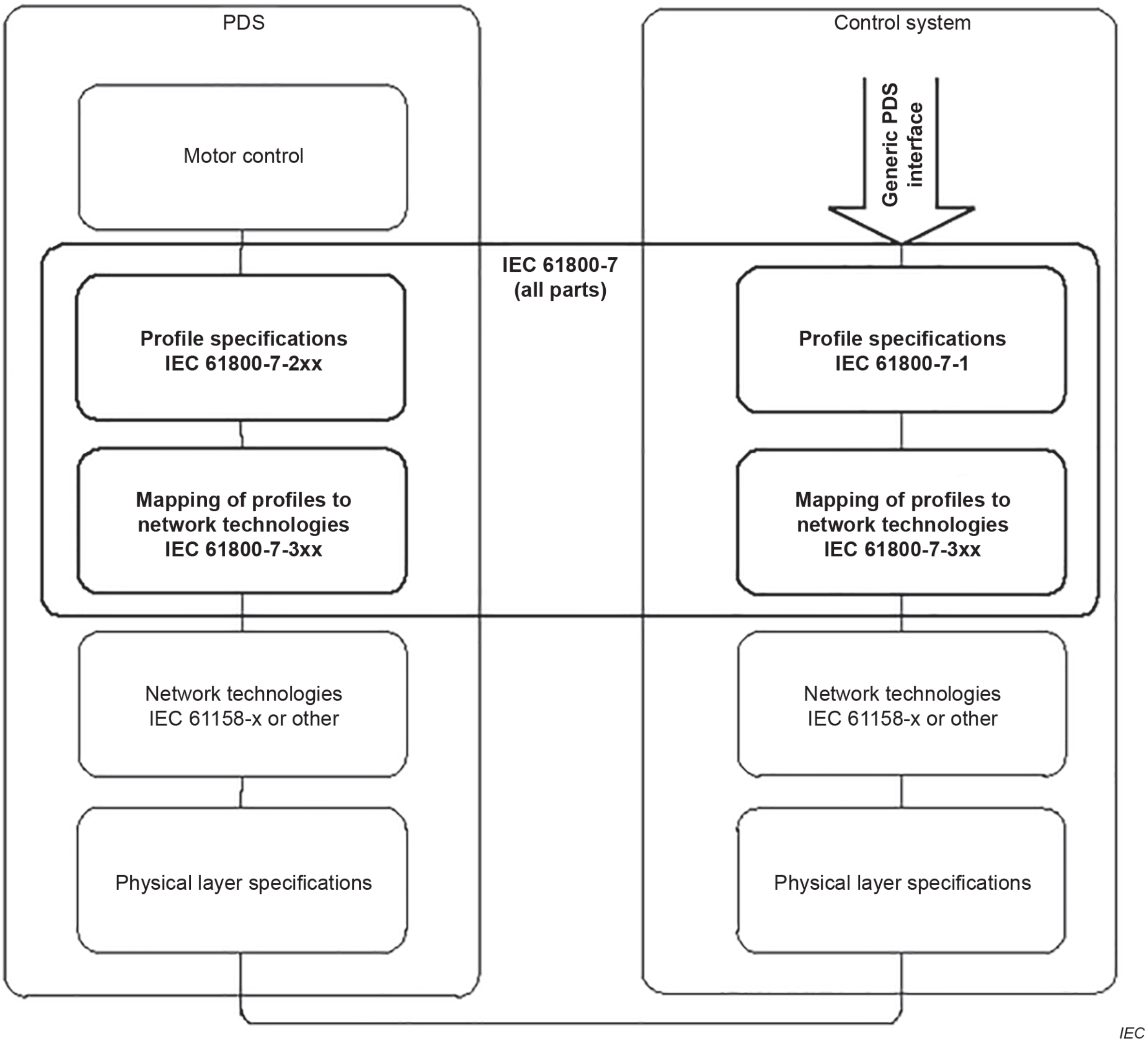


Figure 20 – Example of relationship of IEC 61800-7 (all parts) to control system software and the *BDM/CDM/PDS*

NOTE 2 Other network technologies can be applicable (e.g. EN 50325-4 or other).

For compliance, see 6.6.9.

5.12 Voltage on *power interface*

The voltage interface between the *CDM* and the *motor* is a topic, which might require special consideration, to ensure compatibility between *CDM* and *motor*.

For applications where the voltage interface is of importance, IEC TS 61800-8 can provide further information about the determination of voltages on the *power interface*.

IEC TS 61800-8 provides information about determination of the voltage on the *power interface* for:

- indirect *converter* of the voltage source type, with single-phase *rectifier* as line side *converter*;
- indirect *converter* of the voltage source type, with three-phase *rectifiers* as line side *converter*;

- indirect *converter* of the voltage source type, with three-phase active line side *converter* (e.g. *active infeed converter*).

Specification of the *power interface* voltage might be specified by the *manufacturer* following the guidance of IEC TS 61800-8.

For compliance, see 6.6.3.8.5.

5.13 Driven equipment interface

5.13.1 Critical speeds

Special attention should be paid to:

– take into account the influence of the stiffness of the bearing arrangement and the foundation;
– avoid any continuous running with insufficient damping close to lateral critical speeds (±20 %).

In the case of active bearings (e.g. magnetic bearings), continuous operation at lateral critical speeds may be possible.

5.13.2 Torsion analysis

Torsion analysis is an important system design tool for *PDS* and driven equipment to check the torsion stresses in the whole mechanical string, especially, for example in the following operating conditions:

– start-up;
– 1-phase or 3-phase short-circuit on the terminals of the *motor*;
– impact of possible commutation failure of the *converter*;
– impact of the harmonic components of the *torque* in stationary conditions.

A torsion analysis is recommended for the *PDS* and driven equipment, especially in cases where risk of resonance exists between the inertia of the *motor* and the inertia of the driven equipment. The most relevant cases are:

– where the inertia of the driven equipment is higher than the half of the inertia of the *motor*, actually the risk of high torsion stress grows with increasing inertia of the driven equipment (compared to the inertia of the *motor*);
– where commutation failures of the *converter* may cause higher *torque* dynamics than a three-phase short-circuit of the *motor*;
– where within the electromagnetic *torque* (air gap torque) of a *motor*, any frequency components below twice the rated frequency can be expected to exceed 1 % of the nominal *torque* in a steady state or during start-up;
– for any drive systems above 5 MVA;
– where there is a long shaft connection and/or complex mechanical configuration.

For the torsion analysis, the responsible parties should provide:

– the air-gap *torque* pulsations (including the harmonic composition) over the whole *speed* range (typically the *system integrator*);
– the mechanical drawing of the shaft with information on the material attributes for the drive side (typically the *system integrator*);
– information on any load *torque* pulsations (including the harmonic composition) over the whole *speed* range (typically the driven equipment supplier);

– the mechanical drawing of the shaft with information on the material attributes (typically the driven equipment supplier).

5.14 Explosive environment

PDSs may be used in applications involving explosive atmospheres. Considerations include whether the *BDM/CDM* and/or *motor* are located in the explosive atmosphere, and whether the *BDM/CDM* provides a safety control system associated with a hazard related to the explosive atmosphere.

Requirements to achieve the necessary level of safety have been defined in IEC 60079 (all parts).

NOTE 1 IEC TS 60079-42 provides more information regarding the minimum requirements for safety devices required for the safe functioning of equipment with respect to explosion risks.

NOTE 2 IEC 61800-5-2:2016 no more implements appropriate information about PDS used in safety systems related to explosive atmospheres. All this information is now considered in different parts of the IEC 60079 series in revision.

5.15 Earthing requirements

The earthing concept (grounding, earthing, screening) of the drive system should take into account:

– common mode stresses due to the point of earthing of the *PDS*;
– EMC issues.

The protective bonding circuit and the equipotential bonding (its interconnection) between main components should be considered. Typically, it is also necessary to take into account local requirements. It should cover the whole *PDS* (see Figure 21), including:

– the transformer;
– the main *converter*;
– the *motor*.

The following items are important examples:

– the material of the protective bonding;
– the cross-sectional area of the protective bonding;
– the concept of equipotential bonding.

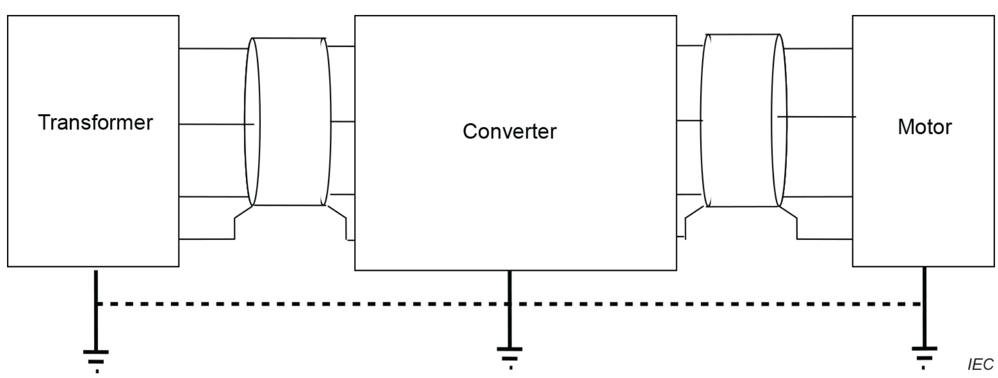


Figure 21 – Example of protective earthing and interconnection of main components

In Figure 21, if both ends of the screen are connected to a protective bonding conductor, the thermal loading of the screen by circulating currents (mostly magnetically induced) should be checked.

Apply IEC 61800-5-1 for safety requirements. This aspect is also relevant to safety and EMC (see IEC 61800-3).

6 Test

6.1 General

Subclauses 6.4 to 6.6 provide guidance for the tests to show compliance with the requirement of Clause 5. According to the different possible methodologies for compliance, as described in 4.2, the responsibility party shall define the test procedure for the selected items from Table 6. For additional requirements that are not part of the basic Table 6, it is also the responsibility of the relevant parties to define the appropriate test procedures to apply for demonstration of the compliance to the additional requirements.

Any test associated with the selected items from the list in Table 6 shall be performed. Also, parties shall agree for the tests category (type, routine or sample tests) to be defined and performed for additional requirements not covered by the list from Table 6.

6.2 Items of individual *PDS* component tests

When covered by particular product standards for design and testing, the *PDS* components should comply with the requirement for testing from these product standards.

For individual *PDS* components, when applicable, the selected tests attached to requirements from Table 6, or considered in addition to the list in Table 6, shall be performed for demonstrating compliance.

Other *PDS* components not listed in Table 6 are considered as part of the CDM. For these *PDS* components, when no particular product standards exist, the test for checking compliance shall be performed according to items selected from the column "CDM supplier" of Table 6.

6.3 Overview of standards and tests for *PDS* components

Subclause 5.2 provides an overview of the major parts of the *BDM/CDM/PDS* and reference information with regard to applicable standards both within IEC 61800 (all parts) and component specific standards. Each *responsible party* should seek to find the appropriate component, product, and/or *installation* standard for their particular application of the *BDM*, *CDM*, *PDS*, Extended system, or any part thereof.

A list of the applicable tests is included in Table 6 with their associated requirements.

6.4 Performance of tests

For the performance and functionality requirements of *BDM/CDM/PDS* and part thereof, when applicable, the selected tests associated with the requirements from Table 6 or considered in addition to the list in Table 6, shall be performed for demonstrating compliance.

Table 6 specifies the different types of tests. Individual type, routine and sample tests of main *PDS* components, i.e. *motor*s, transformers as well as for *BDM* and *CDM*, should be performed as specified in the relevant IEC documents. In this document, additional performance test requirements relevant to the drive system, adjustable speed, harmonics, etc. are outlined.

When not specified in this document or in particular product standards, the test procedures with the relevant acceptance criteria should be provided by the *responsible party*. In particular, where the *BDM*/*CDM*/*PDS* is required to operate in conditions outside the range of values given in this document, then the test conditions should be specified, as defined in the particular individual enquiry or purchasing specification. In any case, the test requirements shall not be less demanding than the operating conditions specified.

6.5 Standard tests for *BDM/CDM/PDS*

6.5.1 General

Table 6 provides references for the tests to be performed for *BDM/CDM/PDS* as well as for the identified individual *PDS* components. Table 6 suggests the relevant tests attached to each listed requirement for performance and functionality.

6.5.2 Current source *converter* zero *power factor* test

A zero *power factor* test can be performed for current source *converter* in place of rated power tests. The *manufacturer* should consider equivalency when using this approach.

A zero *power factor* test means that the *converter* supplies the rated or overload current to the synchronous *motor* under test at the condition of zero *power factor* without mechanical load.

In this case, the *converter* rated current test, the overload capability test, the temperature rise test, the power loss determination, the checking of the attributes of the control equipment and the checking of the protective devices can be performed in an appropriate practical test.

6.6 Test specifications

6.6.1 Visual inspections (*type test*, *sample test* and *routine test*)

Visual inspections should be made:

- as *routine tests*, to check features such as adequacy of labelling, warnings and other aspects;
- as acceptance criteria of individual *type tests*, *sample tests* or *routine tests*, to verify that the requirements of this document have been met.

Visual inspections in *routine test* may be part of the production or assembly process.

Before *type test*, a check should be made that the *BDM*/*CDM*/*PDS* delivered for the test is as expected with respect to supply voltage, input and output ranges, etc.

6.6.2 Supply system earthing conditions

Type tests should be performed to verify complete *BDM*/*CDM* performance with the acceptable earthing systems. These may include:

- neutral to earth;
- line to earth;
- neutral to earth through high impedance;
- isolated neutral (not earthed).

For marking, see Clause 7.

6.6.3 Static performance and rating test

6.6.3.1 General

The satisfactory operation of the equipment should also be verified for the whole range of supply voltage for which it is designed, if this has not yet been done in another test (e.g. checking the protective devices). For the *type test,* the function of the equipment is tested at maximum and minimum values of each *input voltage* range.

Under the input and output rating test in 6.6.3.4 and 6.6.3.5, the following data are measured:

- voltage range U_{L}, current range I_{L} and frequency range f_{L} at the CDM/PDS input;
- voltage range U_{v}, current range I_{v}, power range P_{v} and frequency range f_{v} at the *BDM* input;
- voltage range U_{a1}, current range I_{a}, frequency range f_{a} and power $S_{\mathrm{a}}/P_{\mathrm{a}}$ at *BDM* output;
- voltage range U_{A1}, current range I_{A}, frequency range f_{A} and power $S_{\mathrm{A}}/P_{\mathrm{A}}$ at *CDM* output;
- *torque* range M, power range P_{s}, and *speed* range N at the *motor* shaft;

NOTE 1 Voltage U_{a1} and U_{A1} are measured with an instrument of type and adequate accuracy to indicate the RMS value of the fundamental component of the *converter output voltage*. Currents I_{L}, I_{v}, I_{a} and I_{A} are measured with an AC ammeter of adequate accuracy to indicate the RMS value of the total current.

NOTE 2 The load is the driven equipment or, for test purposes, a simulation of the driven equipment.

The *BDM*/*CDM*/*PDS* should meet the specified functionality and performance as specified by the *manufacturer*.

The load and functionality as specified in 6.6.3.3 may be used for showing compliance.

Regarding measuring circuit, see Figure 22 where physical variables are directly measured or calculated from indirect measurements.

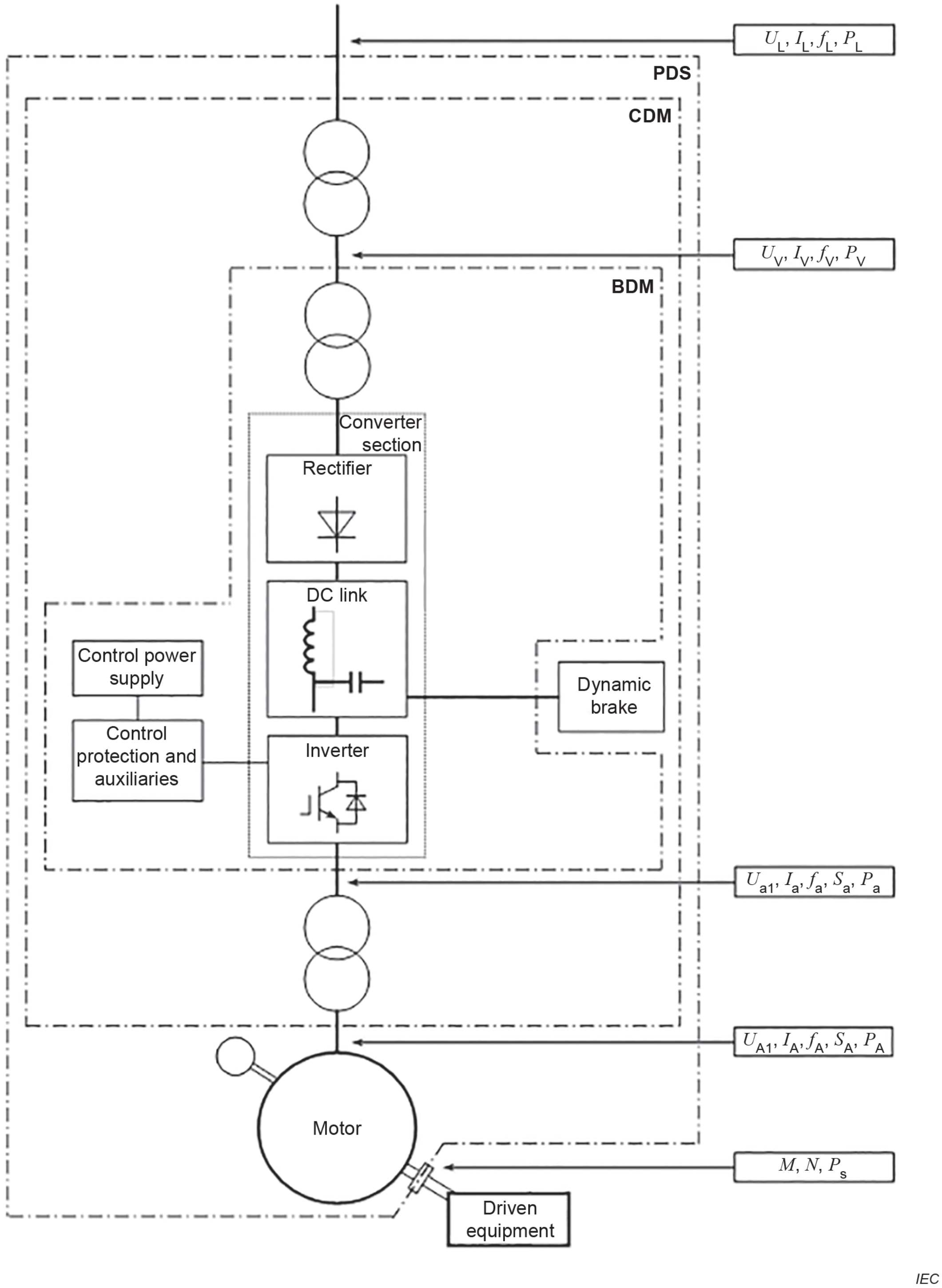


Figure 22 – Measuring circuit of *PDS*

6.6.3.2 Instrumentation for performance testing

The *output currents* and *output voltages* of the *converters* will have varying amounts of harmonics, depending on frequency setting and type of modulation in the *inverter* stage.

6.6.3.3 Load and functionality/performance

6.6.3.3.1 Load test

Based on the specification of the *BDM*/*CDM*/*PDS*, the *manufacturer* may choose to specify a load and functionality/performance test program, under which the specified performance and functionality can be proven under the conditions specified by the *manufacturer*.

The shaft of the *motor* is coupled to a load, which is able to provide conditions to the tested drive, such that the correct function of the control system can be proven. The *motor* should be selected to require adequate current to prove correct *BDM*/*CDM* functions.

A no load test can be used.

NOTE The load is the driven equipment, or a simulation of the driven equipment for test purposes.

6.6.3.3.2 Light load test for *BDM/CDM/PDS*

The light load test is carried out to verify that all parts of the electrical circuit and the cooling of the equipment operate properly together with the main circuit.

For the *routine test*, the *converter* is connected to rated *input voltage*. For the *type test*, the function of the equipment is also tested at maximum and minimum values of the *input voltage*. If series-connected semiconductor devices are used in the arms of the *converter*, the voltage sharing should be checked. This part of the light load test could be conducted at a lower voltage than rated.

6.6.3.4 Input ratings

6.6.3.4.1 General

The specified input rating according to 5.3.2 of the *BDM*/*CDM*/*PDS* should be verified under the rated voltage, current and frequency conditions.

See also Annex B.

6.6.3.4.2 *Input voltage* and *input frequency*

Under the *input voltage* and *input frequency* conditions specified by the *manufacturer*, the specified functionality and performance of the *BDM*/*CDM*/*PDS* should be verified.

6.6.3.4.3 *Input current*

Under the test in 6.6.3.4.2 showing compliance with the *input voltage* and *input frequency* conditions specified by the *manufacturer*, the *input current* range should be measured and specified for the *BDM*/*CDM*/*PDS*.

6.6.3.4.4 Line-side current distortion content

For compliance, apply IEC 61800-3.

6.6.3.5 Output ratings

6.6.3.5.1 General

The specified output rating according to 5.3.3 of the *BDM*/*CDM*/*PDS* should be verified under the rated conditions.

6.6.3.5.2 Voltage rating

The voltage rating of the *BDM*/*CDM*, specified by the *manufacturer* according to 5.3.3.1, should be verified by test.

6.6.3.5.3 *Torque* and current rating

The *torque* and current rating of the *BDM*/*CDM*/*PDS*, specified by the *manufacturer* according to 5.3.3.2, should be verified by test.

NOTE *Torque* can be measured indirectly, for example calculation using power and speed, etc.

6.6.3.5.4 Frequency and speed range

The operating *speed* and frequency range of the *BDM*/*CDM*/*PDS*, specified by the *manufacturer* according to 5.3.3.2, should be verified by test.

The functional test should consist of at least the following:

– starting and acceleration to minimum operating *speed*, according to the load parameters;
– stable operation at a reasonable number of *speed* settings, if possible, including the *rated speed* and the maximum *speed*, if different from the rated value;
– stable acceleration and deceleration between the above-mentioned operating speeds.

NOTE For the purpose of testing, some additional inertia might be appropriate.

6.6.3.5.5 Overcurrent/overtorque capability

The overcurrent capability/performance of the *BDM*/*CDM* and the overtorque of the *PDS* can be verified by test.

6.6.3.5.6 Operating *quadrants*

The operating *quadrants* of the *BDM*/*CDM*/*PDS*, specified by the *manufacturer* according to 5.3.4, can be verified by test.

6.6.3.6 Checking the functionality of the control equipment

The *responsible party* should define the control functions and procedures to test them. There are many ways that the proper operation and functionality of the control can be verified by testing. This could be done with a *motor* under load, with a *motor* with no load, or by operating the control by *stimulus* (feedback) and evaluating the response.

NOTE The light load test also checks some of the control functions.

Routine testing of the protection functions/equipment can be done by simulating the failure causes by operating the relevant switches.

For the type testing of the protection functions, the system supplier should propose an appropriate test program.

For steady state performance, see 6.6.3.9.

For dynamic performance and ratings, see 6.6.3.10.

6.6.3.7 Additional tests for special rating

6.6.3.7.1 General

The additional tests are indented to show compliance with certain functionality related to special applications.

6.6.3.7.2 *Power factor*

Power factor of *BDM*/*CDM*/*PDS* input measurements should be made under rated operating conditions.

6.6.3.7.3 Current sharing

If parallel connected devices or equipment are used in the *PDS*, the current sharing should be checked. If selected, this test shall be performed at *rated output current*.

Examples of parallel configurations are:

- a *converter* section made up by more than one *converter* bridge;
- a *converter* section made up by more than one semiconductor valve per arm;
- a *motor* section with *motor* windings in parallel.

If selected, the current sharing shall be adequate to ensure that no device is stressed beyond design values under worst case conditions. The design limits shall be identified before the tests start.

6.6.3.7.4 Voltage division

If two or more *converters* and/or *motor*s, are connected in series, voltage division should be checked so that no overvoltage occurs to *BDM* and/or *motor*s. If selected, the voltage division shall be adequate to ensure that no device is stressed beyond design values under normal operating and single failure conditions. These design limits shall be identified before the tests start.

6.6.3.7.5 Checking of auxiliary devices

The function of all auxiliary devices that are not completely tested in the *BDM/CDM* or *motor* tests should be checked. Examples of such devices are: *motor* fans, lubricating oil pumps fed from the *CDM*, external circuit breakers, disconnect devices, etc.

If convenient, this can be done while performing light load test (see 6.6.3.3).

6.6.3.7.6 Checking of protective measures

Protective measures which are relevant for the electrical, thermal, energy or functional safety of the *BDM*/*CDM*/*PDS* should be evaluated according to IEC 61800-5-1 and IEC 61800-5-2.

Examples of protective measures:

- *motor* overspeed;
- *motor* overvoltage;
- *motor* overload;
- *motor* overtemperature;
- loss of *speed* feedback;
- supply mains undervoltage;

- *BDM/CDM motor* output earth fault or short-circuit between *motor* terminals, etc;
- verification of the emergency stop function, if applicable;
- test of current/ *torque* limiting functions.

Due to the wide variety of protective measures and their combinations, it is not possible to state any general rules in this document for checking these measures.

When checking the protective measures will be done as part of a *routine test* or commissioning test, it should be done, as far as possible, without stressing the components of the equipment above their rated values. Reduced settings are recommended in order to obtain reduced stresses.

6.6.3.7.7 Checking attributes under unusual service conditions

Unusual climatic conditions may require special coating on electronic assemblies and/or cabinet. In extreme temperature conditions, an air conditioner or heater may be provided.

Unusual service conditions are mainly environmental conditions, such as temperature, humidity, salty air, altitude, etc. beyond IEC standard specifications for the relevant equipment. Such conditions might require:

– special design; and/or
– rating criteria; and/or
– extra protective coating; and/or
– etc.

6.6.3.7.8 Interphase ripple voltage and ripple current

Apply IEC 61800-3 for EMC requirements.

6.6.3.8 Additional test (effect on *motor*) for special rating

6.6.3.8.1 General

Due to the nature of the *output current* and *output voltage* of the *BDM*/*CDM,* some additional tests to verify the compatibility between *motor* and *BDM*/*CDM* can be considered.

As these effects depend on the application, no specific test for 6.6.3.8.2 to 6.6.3.8.5 can be specified in this document.

IEC TS 61800-8 and IEC TS 62578 provide additional information about the use of filter to reduce some of these phenomena.

6.6.3.8.2 *Motor* vibration

This test may be carried out at various *speeds* and loads to identify any *BDM/CDM* effects on *motor* vibration.

The vibration tests in accordance with IEC 60034-14 is likely needed.

6.6.3.8.3 Sonic pressure and sound level

PDS may be required to be tested for sonic pressure and sound level (see 5.9.2.5). The test should be done over the operating *speed* range and load range. Acceptable sonic pressure and sound level are defined by local regulation. For the most relevant standards which define these tests, see 5.9.2.5.

The application of the *PDS* should be evaluated to determine if more stringent local regulations may apply.

6.6.3.8.4 Bearing current

Bearing currents may result due to common-mode effects and harmonics in *motor* voltage and current. While these currents are small in magnitude, they may cause damage to either anti-friction or sleeve bearings.

IEC TS 61800-8 provides information about bearing current including the use of a filter to reduce bearing currents.

There are many methods available that can be used to verify this current is within an acceptable level.

NOTE See also IEC 60034-25.

6.6.3.8.5 Voltage stress of the *motor* winding insulation system

IEC TS 61800-8 provides information about the requirements for insulation and for the determination of the voltage on the *power interface* between *BDM/CDM* and *motor*.

6.6.3.9 Steady state performance

The *manufacturer* should verify the data given in the documentation.

6.6.3.10 Dynamic performance and rating

6.6.3.10.1 General

Under normal operating conditions, the dynamic performance and rating of the *BDM*/*CDM*/*PDS* should be verified.

6.6.3.10.2 Current limit and current loop

These tests characterize the dynamic performance of the *BDM*/*CDM* or of the *PDS* independently from the driven equipment.

Two items can be tested.

a) Current limit

   An incremental load change is provided to require the *CDM* to reach its pre-set current limit point (as an alternative, an incremental step *speed* change into adequate rotational inertia can provide a transient load causing the *CDM* to reach the current limit set point). The rise time of current, overshoot magnitude and duration and damping characteristics may then be analyzed.

b) Step response to current reference

   Current loop bandwidth can be measured with a small step change of current reference within a linear or quasi linear area. This test can include nonlinear area.

These tests should be carried out at different speeds to be chosen near 0,50 % *rated speed*, 100 % *rated speed*, and *maximum rated speed*.

It is usually necessary to adjust the *speed* by using a machine coupled to the shaft of the *motor* under test (which is itself adjusting the *torque* by means of current following the reference).

By adequate scaling, the current limit function might be tested if relevant.

6.6.3.10.3 *Speed* loop

A step in *speed* reference is provided and correctly selected to accommodate the following tests. This test can be carried out under no load or light load conditions. See 6.6.3.3.

The current limitation and its value are checked with a large step change of *speed* reference reaching the current limit.

The drive output *speed* response is measured without reaching any limits (normally done within 50 % *rated speed*, at 100 % *rated speed*, and at *maximum rated speed)*.

A step in load may be provided to allow measurement of the consequent *speed* response. This may be carried out while performing rating test 6.6.3.3. If selected, the load step shall be chosen so that no limitations are reached.

6.6.3.10.4 *Torque* pulsation

Relative levels of air-gap *torque* pulsation may be measured under no load conditions using *speed* changes, provided that adequately sensitive *speed* measurement devices are coupled to the shaft. Ideally, air-gap *torque* pulsation arising within a specific *PDS* should be measured with a known load inertia, proper load/*PDS* mechanical coupling and shaft mounted *torque* sensing equipment.

6.6.3.10.5 Automatic restart

If automatic restart is provided and selected, it shall be verified for the specified power outage duration. This function shall be coordinated with emergency stop and inhibited if required.

Restriction on automatic restart may be considered.

6.6.3.11 Fault supervision

The *BDM*/*CDM*/*PDS* ability to detect internal and external faults should be tested. This also includes the audible, visual and electronic alarm for the *customer*.

6.6.3.12 I/O devices

The functionality of all input/output *port* should be proven.

Examples of input output *ports* are:

- analog input/output ports;
- digital input/output ports;
- relay ports;
- power supply input/output ports.

6.6.4 Electrical safety

For compliance, apply IEC 61800-5-1.

6.6.5 Functional safety

For compliance, apply IEC 61800-5-2.

6.6.6 EMC

For compliance, apply IEC 61800-3.

6.6.7 Ecodesign

For compliance, apply IEC 61800-9-2.

6.6.8 Environmental condition tests

6.6.8.1 General

The climatic tests of 6.6.8.3 to 6.6.8.11, if selected, shall be specified with the purpose of showing compliance with the static and dynamic performance and rating of the *BDM*/*CDM*/*PDS*.

Tests on sub-parts or sub-assemblies are permitted if it can be verified that the test results will not be affected compared to the tests of the complete assembled *BDM/CDM/PDS.*

The climatic tests of 6.6.8.3 to 6.6.8.11 might be referenced by other parts of the IEC 61800 series, in which case the acceptance criteria should be specified separately.

In 6.6.8, the values of the severity levels of IEC 60068 (all parts) with dated reference are copied and provided in the relevant clause for convenience. The levels of test conditions are informative, and the levels of IEC 60068 (all parts) take precedence in case of deviations.

6.6.8.2 Acceptance criteria

The following acceptance criteria shall be satisfied after for the environmental test(s) selected, if any:

- no mechanical damage or cracks in the enclosure which will reduce the IP classification;
- show compliance with the static and dynamic performance and rating of the *BDM*/*CDM*/*PDS* according to 6.6.3.3.

6.6.8.3 Temperature tests

6.6.8.3.1 Temperature rise test

The temperature rise test required in IEC 61800-5-1 may not consider temperature measurement locations that are relevant for evaluating performance or functionality. The test should be done following the requirements set in IEC 61800-5-1 and IEC 61800-5-2 with the addition of any measurement locations required for evaluation of performance or functionality. For minimum compliance, apply IEC 61800-5-1 for safety and IEC 61800-5-2 for functional safety as appropriate.

6.6.8.3.2 Dry heat test (steady state)

Certain application can have requirements for this topic which can be derived from IEC 60721 (all parts).

For safety compliance, apply IEC 61800-5-1.

6.6.8.3.3 Load duty profile

This test generally requires information from the *customer*.

If a specific temperature rating is specified based on a selected load duty profile, the temperature test shall be performed according to the specified load duty profile (see 5.10).

The shaft of the *motor* is coupled to a load, which is capable of providing the specified load duty profile over a long-term run, to verify that the temperature in the equipment reaches stable conditions within ratings.

IEC TR 61800-6 provides further information about load profiles.

6.6.8.4 Damp heat test (steady state)

Certain application can have requirements for this topic which can be derived from IEC 60721 (all parts).

For safety compliance, apply IEC 61800-5-1.

6.6.8.5 Vibration test (*type test*)

For vibration ratings past the minimum safety requirements provided by IEC 61800-5-1, use IEC 60721 (all parts) for guidance of test conditions and requirements. Test should be performed to verify *manufacturer* specifications.

For safety compliance, apply IEC 61800-5-1.

6.6.8.6 Shock test (*type test*)

To verify the ability against mechanical shock strength, it is recommended to evaluate the *BDM/CDM/PDS* for use within machines by:

a) tests defined according to the conditions specified in Table 21; or
b) calculation or simulation based on tests, as defined in 6.6.8.6, on a representative model of *BDM/CDM/PDS*.

Table 21 – Shock test

Subject	Test conditions
Test reference	Test Ea of IEC 60068-2-27:2008
Requirement reference	Table 20
Preconditioning	According to 6.6.1
Conditions Motion Shock amplitude/time Number of shocks Detail of mounting	Power supply disconnected Half-sine pulse 50 m/s^2 (5 g) 30 ms 3 per axis on each of three mutually perpendicular axes According to *BDM/CDM/PDS manufacturer*'s specification
Acceptance criteria	6.6.8.2
Where the *manufacturer* specifies shock levels that are greater than those above, the higher levels shall be used for the test. The acceptance criteria shall not be changed. Where the environmental conditions are known to be lower, the *BDM/CDM/PDS manufacturer* might specify lower level or no vibration levels test than those specified in this table. The acceptance criteria shall not be changed.	

6.6.8.7 Salt mist test (*type test*)

Certain application can have requirements for this topic which can be derived from IEC 60721 (all parts).

For safety compliance, apply IEC 61800-5-1.

6.6.8.8 Dust test (*type test*)

Certain application can have requirements for this topic which can be derived from IEC 60721 (all parts).

For safety compliance, apply IEC 61800-5-1.

6.6.8.9 Sand test (*type test*)

Certain application can have requirements for this topic which can be derived from IEC 60721 (all parts).

For safety compliance, apply IEC 61800-5-1.

6.6.8.10 Water test (*type test)*

Water test is relevant for second character IP.

For safety compliance, apply IEC 61800-5-1.

6.6.8.11 Hydrostatic pressure test (*type test* and *routine test*)

For safety compliance, apply IEC 61800-5-1.

6.6.9 Communication profiles

For compliance, apply IEC 61800-7 (all parts).

6.6.10 Explosive atmosphere environment

For compliance, apply IEC 60079 (all parts) and specifically IEC TS 60079-42.

7 Information and marking requirements

7.1 General

Clause 7 provides a minimum number of information and markings, and several other standards in the IEC 61800 series provide further requirements for marking which should be taken into consideration if applicable:

- electrical safety information according to IEC 61800-5-1;
- functional safety information according to IEC 61800-5-2 if applicable;
- EMC information according to IEC 61800-3 if applicable;
- energy *efficiency* information according to IEC 61800-9-2 if applicable.

The safety marking requirements of IEC 61800-5-1 and IEC 61800-5-2, EMC marking requirements of IEC 61800-3 and the energy *efficiency* marking requirements of IEC 61800-9-2 should be taken into consideration where applicable.

NOTE In general, marking and information can be provided by marking on product and/or information in paper form or electronic form (WEB, CD-ROM or similar).

7.2 Marking on product

Marking on the product should provide the necessary information needed to ensure full identification and traceability of the *manufacturer*.

The following minimum information should be supplied on the rating plate of the *BDM/CDM/PDS*:

- the *manufacturer's* name;
- equipment identification (model number, serial number, and year of manufacture);
- input and output ratings.

For *PDS,* in addition, the rated *output power* (P_N), *rated torque* (M_N) and *rated speed* (N_N) should be marked.

NOTE The word "marking" also includes labelling on the product.

7.3 Information to be supplied with the *PDS* or *BDM/CDM*

The following information should be supplied with the furnished equipment:

- information necessary for calibrating components, devices, and subassemblies which are intended to be adjusted by the *end user*;
- operating instructions, including all information necessary to operate the *BDM*/*CDM*/*PDS*;
- acceptable supply systems earthing conditions for the *BDM/CDM/PDS*. The unacceptable systems should be indicated as:
  - forbidden; or
  - with modification of performance, which should be quantified through *type test*;
- device substitution;
- environmental rating.

The environmental rating in Table 12 should be indicated in the documentation.

The specific environmental conditions in 5.9.2.1.1 or 5.9.2.2.1 should be identified in the operating manual.

7.4 Information to be supplied or made available

The following information should be supplied or made available:

- maintenance and service instructions, including information for locating and replacing faulty components or subassemblies;
- energy absorption rating of the resistive braking (slowdown) and resistive braking (stop) circuits.

For *PDS* speed, information should be supplied, including:

- *rated speed* (N_N) [r/min];
- *maximum rated speed* (N_{NMax}) [r/min];
- *minimum rated speed* (N_{Min}) [r/min];
- *maximum rated safe speed* (N_{SNMax}) [r/min].

Information may be supplied by an electronic media if specified.

7.5 Safety and warning

7.5.1 Safety and warning labels

Safety and warning labels should meet the requirement in:

- IEC 61800-5-1 for electrical safety,
- IEC 61800-5-2 for functional safety (only if applicable),
- IEC 61800-3 for EMC (only if applicable),
- IEC 61800-9-2 for energy *efficiency* (only if applicable).

7.5.2 Additional safety considerations of a *PDS*

The *PDS* may be coupled to driven equipment. All protection systems of the driven equipment, including the shaft of the *motor*, are defined by the *customer*. The *customer* shall provide to the *manufacturer* of the *PDS* all the necessary specifications which are consequences of machinery safety and have to be included in the control of the *PDS*.

The *PDS* is mainly electrical equipment and the safety risk is mainly electrical. The safety risk is predominantly electrical for the *BDM/CDM*.

For these reasons, the *BDM/CDM*/*PDS* should comply with IEC 61800-5-1.

Compliance with IEC 61800-5-1 does not, in itself, ensure compliance with all safety requirements for the final system or application. Detailed safety requirements for the final system or application are defined in their product or extended product safety standards.

Following standards are examples that may be applicable:

- IEC 60204-1 for electrical equipment on machinery;
- IEC 60364 (all parts) for low-voltage electrical *installations*;
- IEC 61439-1 for switchgear.

Annex A
(informative)

Classification of *PDS* into low-voltage system and high-voltage system

A.1 General

The purpose of Annex A is to classify *PDS* with AC power port(s) into low-voltage system and high-voltage system. See definition 3.30 and 3.16 for low voltage and high voltage, respectively. A *BDM* is always a subcomponent of a CDM, i.e. every PDS contains at least one CDM.

A.2 Classification of *PDS* by voltage

The Figure A.1 suggests the basic configuration of a PDS to support more easily the examples provided in Clause A.3. More detailed information of the PDS content is given by the example of Figure 2.

A *converter* transformer or a device such as a reactor, which is essential for power conversion if any, is a part of *BDM*. An output transformer is optional and a part of *CDM* (outside of *BDM*). A supply transformer is optional and outside of *PDS*. An input transformer, which is neither a supply transformer nor essential for power conversion but necessary for other reason/purpose if any, is optional and a part of *CDM* (outside of *BDM*).

The basic classification of PDS by voltage are described in Table 5 and Table A.1. In the only case where all *rated input/output voltages* of *BDM/CDM* are low-voltage, the *PDS* is a low-voltage system.

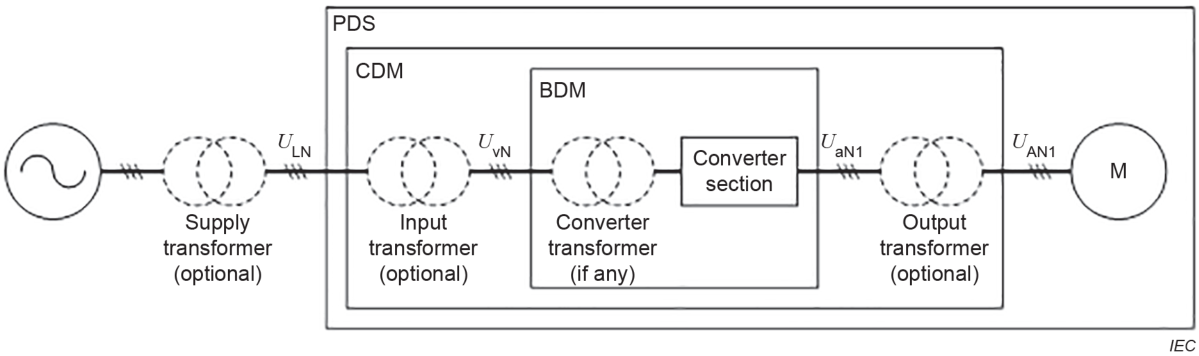


Figure A.1 – Basic configuration of *PDS*

Table A.1 – Basic classification of PDS by voltage

***CDM* voltage ratings**				**Classification of *PDS* by voltage**
Input U_{LN}	***BDM* voltage ratings**		**Output U_{AN1}**	
	Input U_{vN}	**Output U_{aN1}**		
Low-voltage	Low-voltage	Low-voltage	Low-voltage	Low-voltage
Low-voltage	Low-voltage	Low-voltage	High-voltage	High-voltage
Low-voltage	Low-voltage	High-voltage	Low-voltage	
Low-voltage	Low-voltage	High-voltage	High-voltage	
Low-voltage	High-voltage	Low-voltage	Low-voltage	
Low-voltage	High-voltage	Low-voltage	High-voltage	
Low-voltage	High-voltage	High-voltage	Low-voltage	
Low-voltage	High-voltage	High-voltage	High-voltage	
High-voltage	Low-voltage	Low-voltage	Low-voltage	
High-voltage	Low-voltage	Low-voltage	High-voltage	
High-voltage	Low-voltage	High-voltage	Low-voltage	
High-voltage	Low-voltage	High-voltage	High-voltage	
High-voltage	High-voltage	Low-voltage	Low-voltage	
High-voltage	High-voltage	Low-voltage	High-voltage	
High-voltage	High-voltage	High-voltage	Low-voltage	
High-voltage	High-voltage	High-voltage	High-voltage	

A.3 Examples

A.3.1 *PDS* with a supply transformer

Figure A.2 shows an example of *PDS* with a step-down supply transformer and no *converter*/output transformer as one of typical configurations.

The *rated input/output voltages* of *BDM/CDM* are AC 440 V. This *PDS* is classified into low-voltage system.

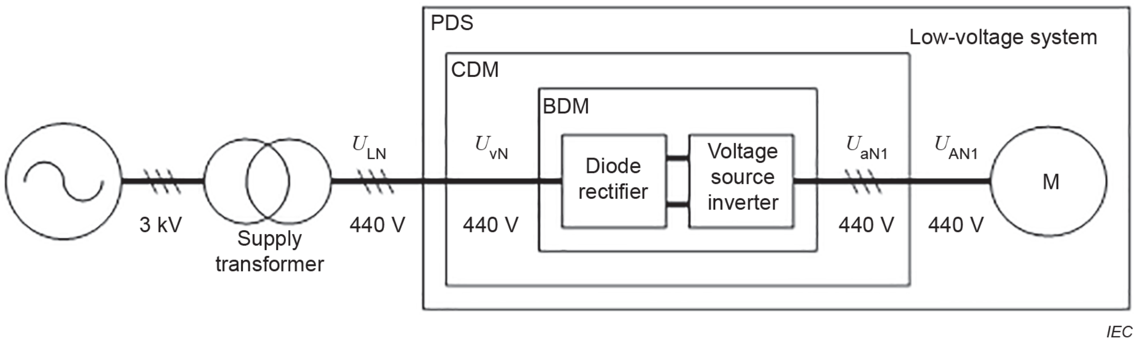


Figure A.2 – Example of *low-voltage PDS* with a supply transformer

A.3.2 *PDS* with an *active infeed converter*

Figure A.3 shows an example of *PDS* with an *active infeed converter* and no output transformer as one of typical configurations. An *active infeed converter* needs an inductive element in the AC side. The AC choke is therefore essential for power conversion and a part of *BDM*.

The *rated input/output voltages* of *BDM/CDM* are AC 440 V. This *PDS* is classified into low-voltage system.

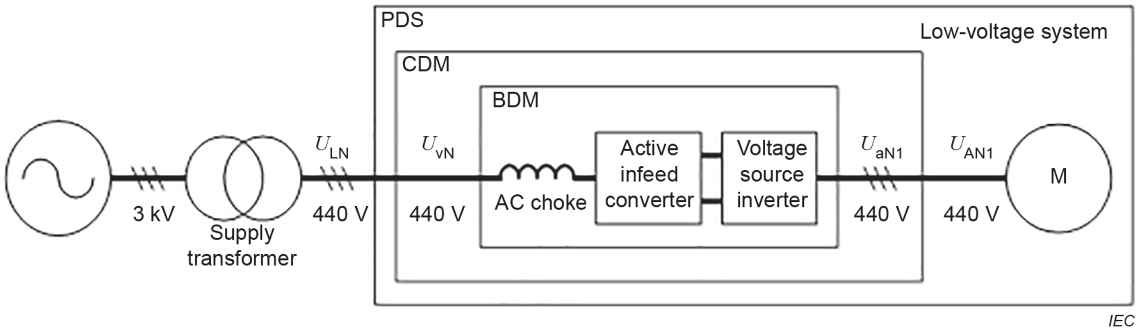


Figure A.3 – Example of *low-voltage PDS* with an *active infeed converter*

Figure A.4 shows another example of *PDS* with an *active infeed converter*. In this *PDS*, leakage inductance of a transformer in the AC side is used as an inductive element instead of an AC choke. The AC side transformer is therefore essential for power conversion and a part of *BDM* as a *converter* transformer.

The *rated input voltages* of *BDM/CDM* are AC 3 kV. This *PDS* is classified into high-voltage system.

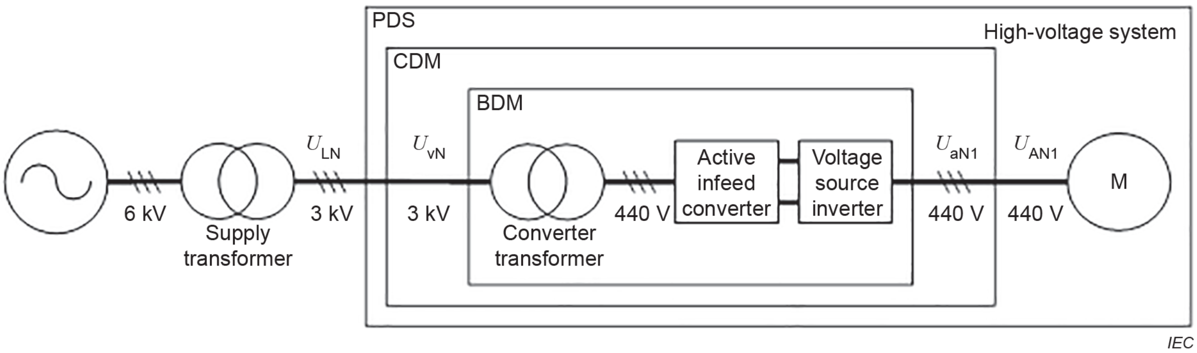


Figure A.4 – Example of *high-voltage PDS* with an *active infeed converter*

A.3.3 *PDS* with an output transformer

Figure A.5 shows an example of *PDS* with a step-down supply transformer and a step-up output transformer.

The *rated output voltage* of *CDM* is AC 3 kV. This *PDS* is classified into high-voltage system.

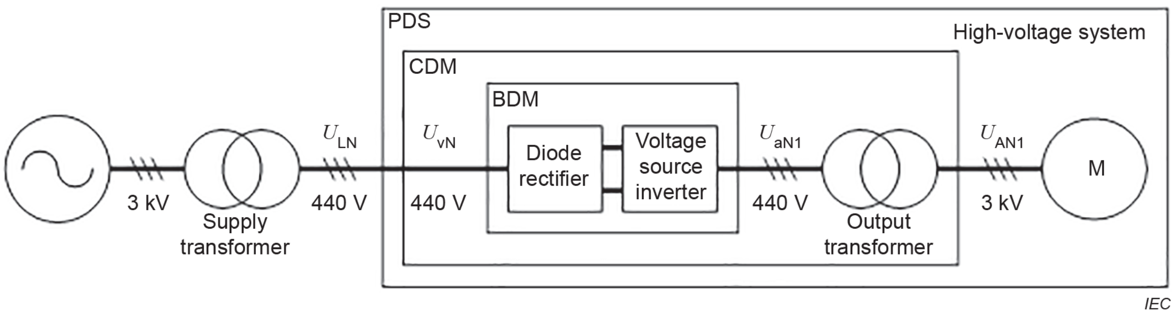


Figure A.5 – Example of *high-voltage PDS* with an output transformer

A.3.4 *PDS* with a common *DC link*

Figure A.6 shows an example of *PDS* with a common *DC link* and multiple *motors*.

The *rated input/output voltages* of *BDM/CDM* are AC 440 V. This *PDS* is classified into low-voltage system.

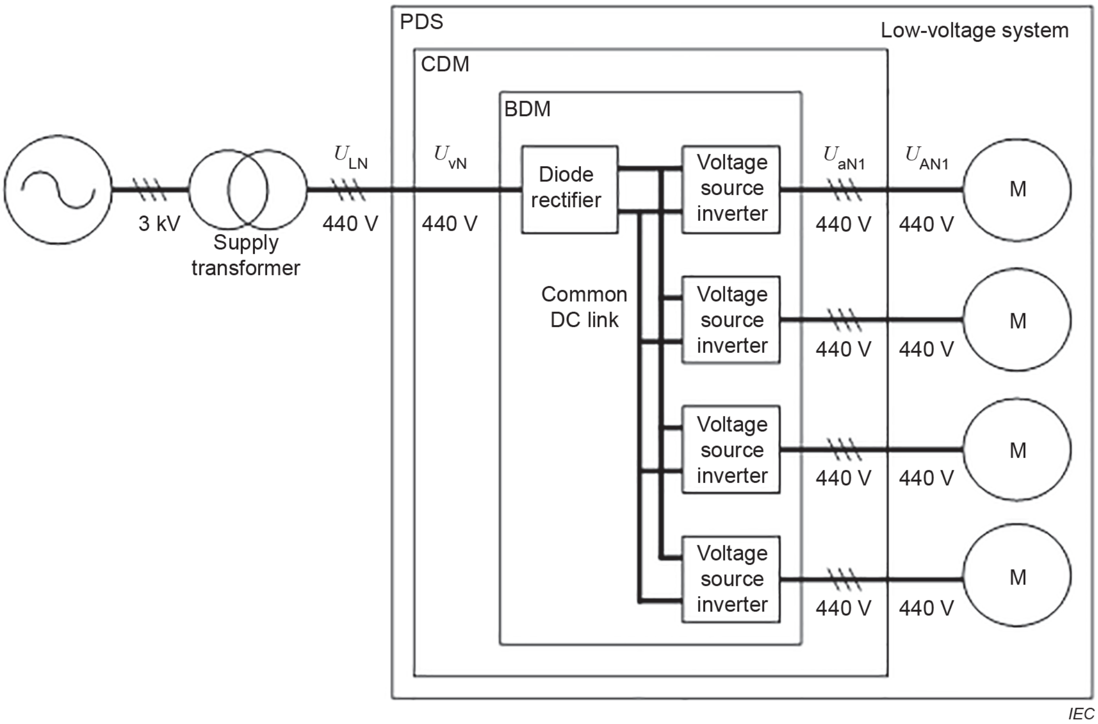


Figure A.6 – Example of *low-voltage PDS* with a common *DC link*

Figure A.7 shows another example of *PDS* with a common *DC link* and multiple *motors*. In this *PDS*, a step-up output transformer is connected to one of *inverters*.

One of the *rated output voltages* of *CDM* is AC 3 kV. This *PDS* is classified into high-voltage system.

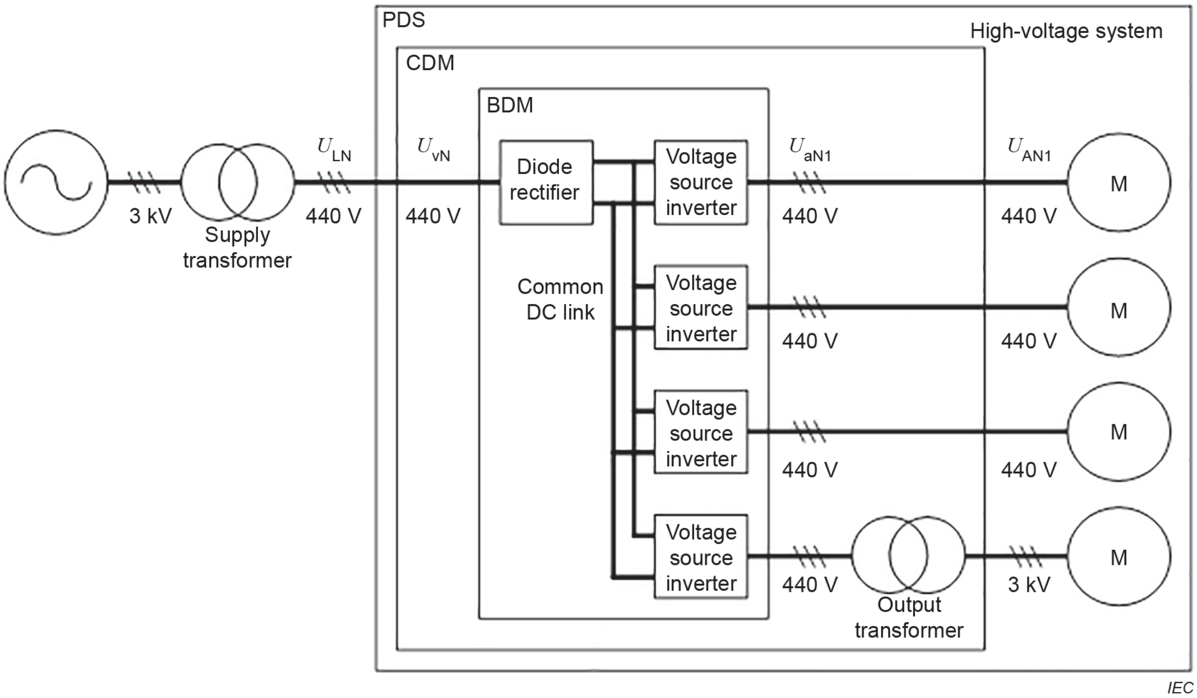


Figure A.7 – Example of *high-voltage PDS* with a common *DC link*

A.3.5 *PDS* with a step-up chopper

Figure A.8 shows an example of *PDS* with a step-up chopper.

The *rated output voltages* of *BDM/CDM* are AC 1 200 V. This *PDS* is classified into high-voltage system.

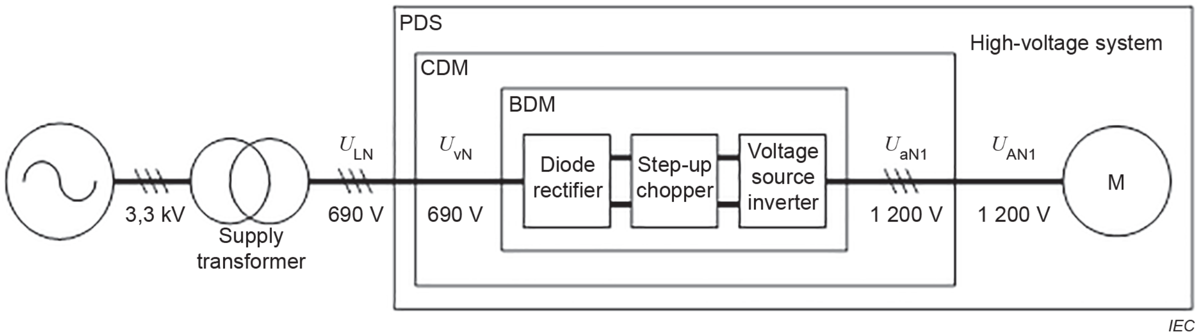


Figure A.8 – Example of *high-voltage PDS* with a step-up chopper

A.3.6 *PDS* with parallel-connected line-side *converters*

Figure A.9 shows an example of *PDS* with two parallel-connected line-side *converter*s.

The *rated input voltage* of each diode *rectifier* in *BDM* and the *rated output voltages* of *BDM/CDM* are AC 660 V. This *PDS* is classified into low-voltage system.

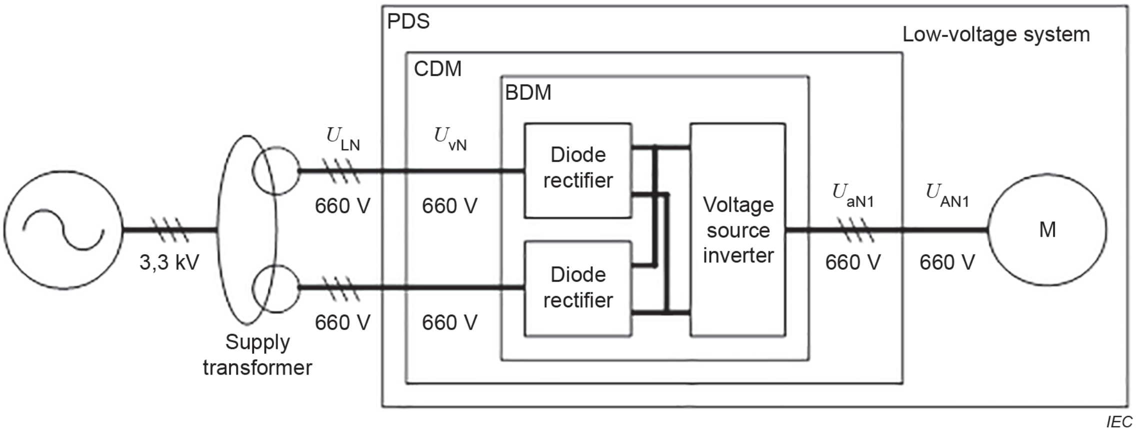


Figure A.9 – Example of *low-voltage PDS* with parallel-connected *rectifiers*

Figure A.10 shows another example of *PDS* with two parallel-connected line-side *converter*s. *BDM* has a diode *rectifier* and an *active infeed converter*.

The *rated input voltage* of the diode *rectifier* is AC 1 100 V and that of the *active infeed converter* is AC 900 V, and the higher *rated input voltage* is AC 1 100 V. This *PDS* is classified into high-voltage system.

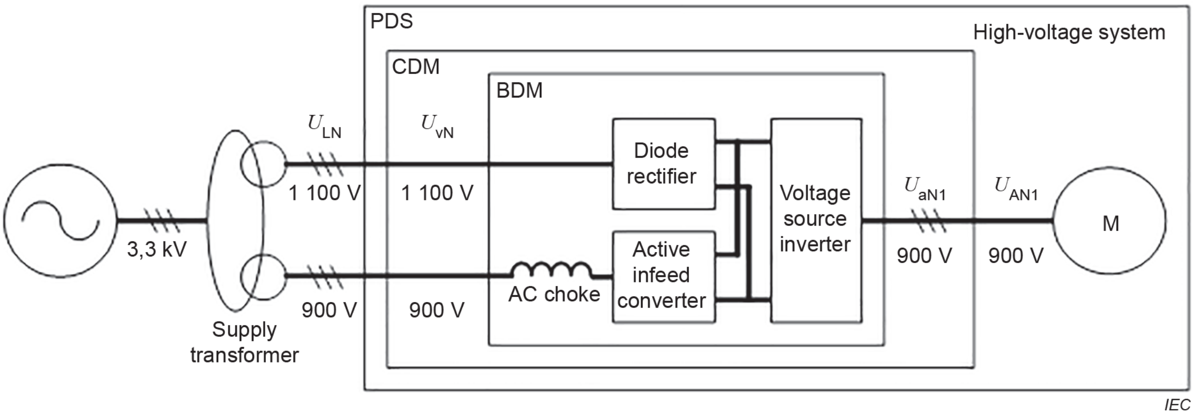


Figure A.10 – Example of *high-voltage PDS* with parallel-connected line-side *converter*s

A.3.7 *PDS* with series-connected line-side *converters*

Figure A.11 shows an example of *PDS* with two series-connected *rectifiers.* In this *PDS*, each input of two diode *rectifiers* is mutually isolated and the AC side transformer is therefore essential for power conversion and a part of *BDM* as a *converter* transformer.

The *rated input voltages* of *BDM/CDM* are AC 3,3 kV. This *PDS* is classified into high-voltage system.

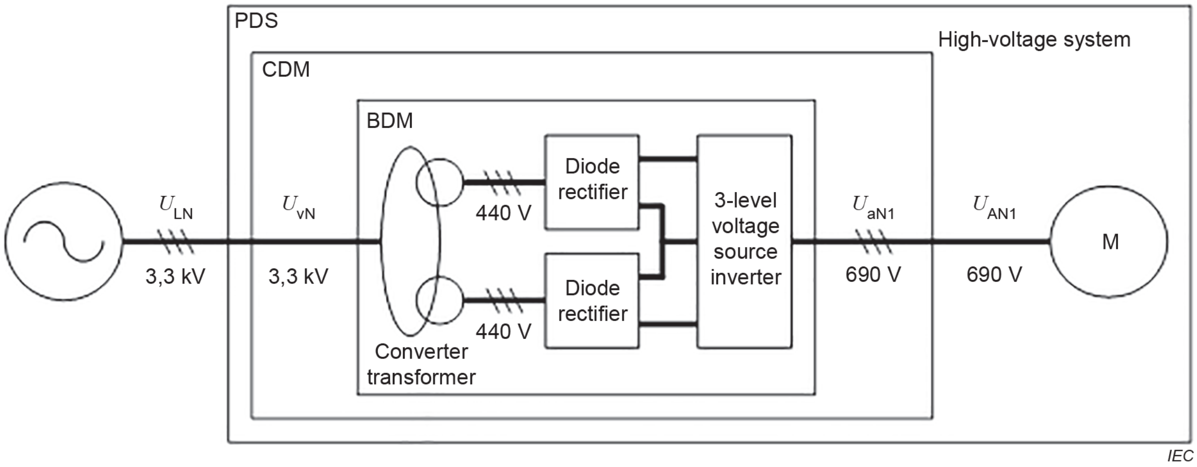


Figure A.11 – Example of *high-voltage PDS* with series-connected *rectifiers*

Figure A.12 shows another example of *PDS* with two series-connected *rectifiers.*

The *rated input voltages* of *BDM/CDM* are AC 3,3 kV and the *rated output voltages* of *BDM/CDM* are AC 1 200 V. This *PDS* is classified into high-voltage system.

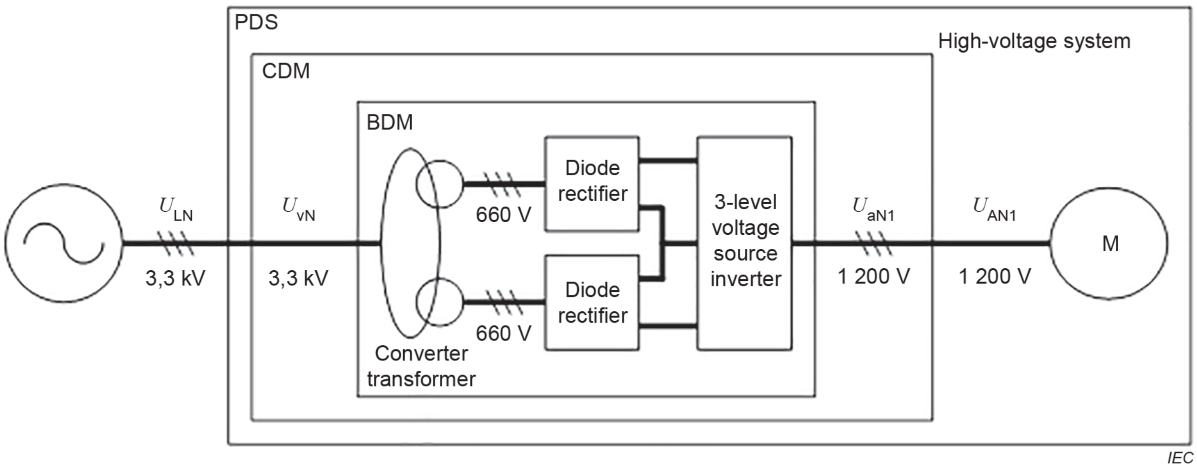


Figure A.12 – Example of *high-voltage PDS* with series-connected *rectifiers*

A.3.8 *PDS* with star-connected *inverters*

Figure A.13 shows an example of *PDS* with star-connected *inverter*s. In this *PDS*, each input of three diode *rectifiers* is mutually isolated and the AC side transformer is therefore essential for power conversion and a part of *BDM* as a *converter* transformer.

The *rated input voltages* of *BDM/CDM* are AC 3,3 kV and the *rated output voltages* of *BDM/CDM* are AC 1 200 V. This *PDS* is classified into high-voltage system.

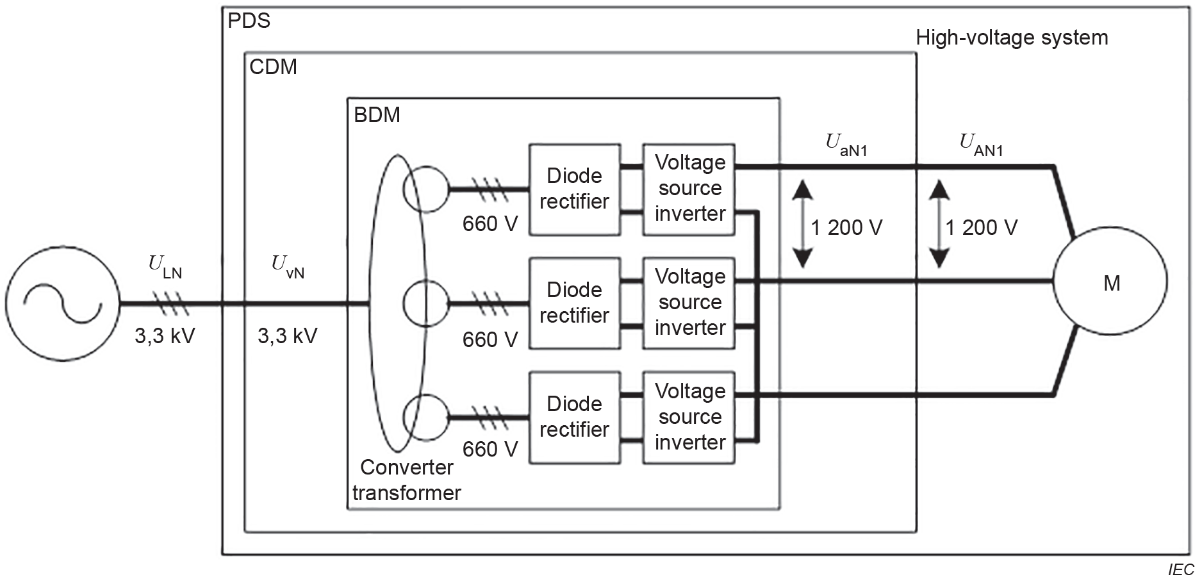


Figure A.13 – Example of *high-voltage PDS* with star-connected *inverter*s

A.3.9 *PDS* with a multilevel *inverter*

Figure A.14 shows an example of *PDS* with a multilevel *inverter* which has cascaded power modules and Figure A.15 shows an example of the power module. In this *PDS*, each input of nine power modules is mutually isolated and the AC side transformer is therefore essential for power conversion and a part of *BDM* as a *converter* transformer.

The *rated input/output voltages* of *BDM/CDM* are AC 3,3 kV. This *PDS* is classified into high-voltage system.

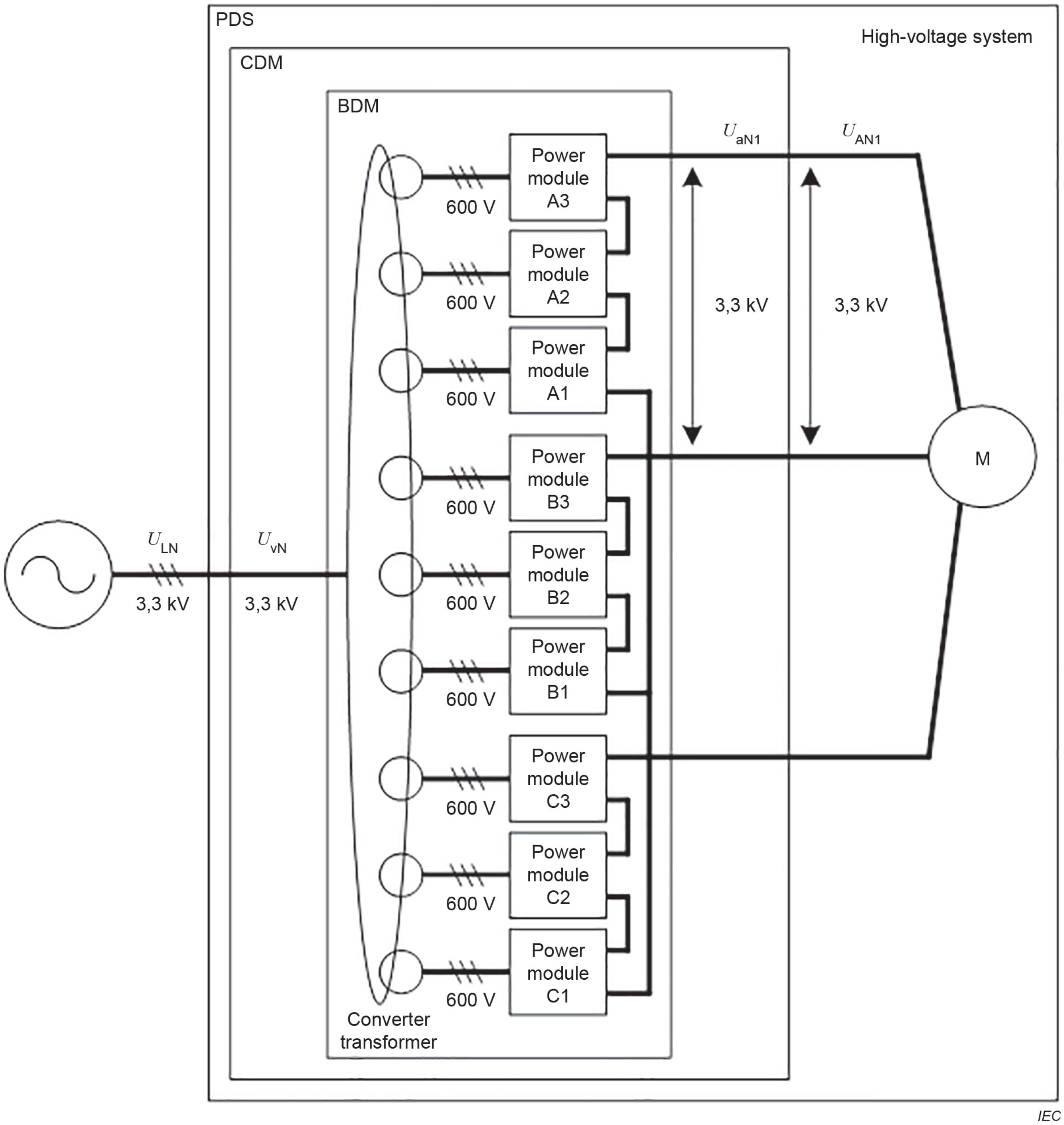


Figure A.14 – Example of *high-voltage PDS* with a multilevel *inverter*

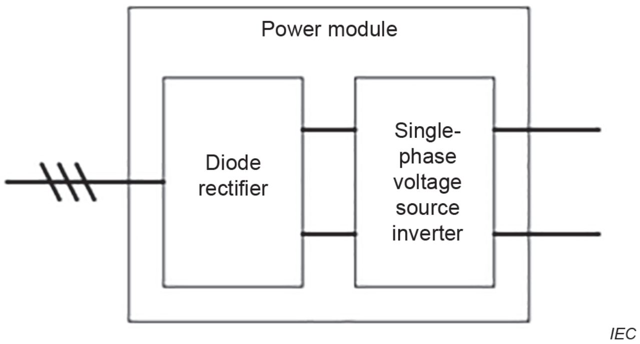


Figure A.15 – Example of a power module

A.3.10 Multiple *PDSs* with a common supply transformer

Figure A.16 shows an example of four *PDSs* with a common supply transformer. In this case, each *PDS* is classified individually.

For *PDS*-1, the *rated input/output voltages* of *BDM/CDM* are AC 400 V and this is classified into low-voltage system.

For *PDS*-2, the *rated output voltages* of *BDM/CDM* are AC 3 kV and this is classified into high-voltage system.

For *PDS*-3, the *rated input/output voltages* of *BDM/CDM* are AC 400 V and this is classified into low-voltage system.

For *PDS*-4, the *rated output voltage* of *CDM* is AC 3 kV and this is classified into high-voltage system.

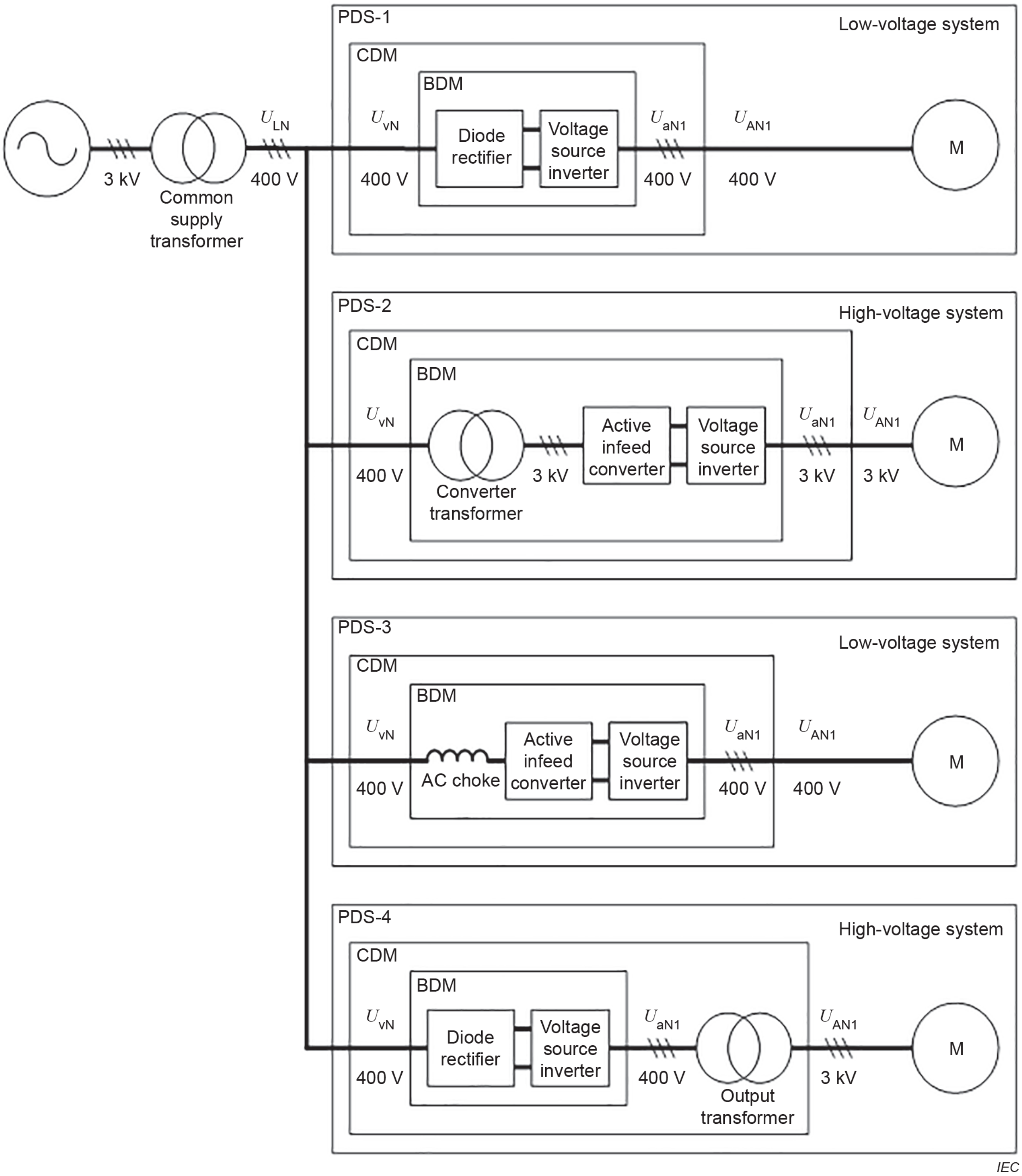


Figure A.16 – Example of multiple *low-voltage/high-voltage PDSs* with a common supply transformer

Annex B
(informative)

Determination of the *input current* of *BDM/CDM/PDS*

Annex B provides information about determination of the RMS value of the steady state *input current* according to 5.3.2.3 and the load duty profile *input currents* according to 5.10.

The RMS value of the *input current* I_{vN} of *BDM/CDM/PDS* is provided to the *system integrator* for dimensioning of the input wire and the upstream protection elements. The wave shape of the *input current* is non-sinusoidal depending on the topology of the *rectifier* and the source impedance of the supply. Figure B.1 shows an example of an *input current.*

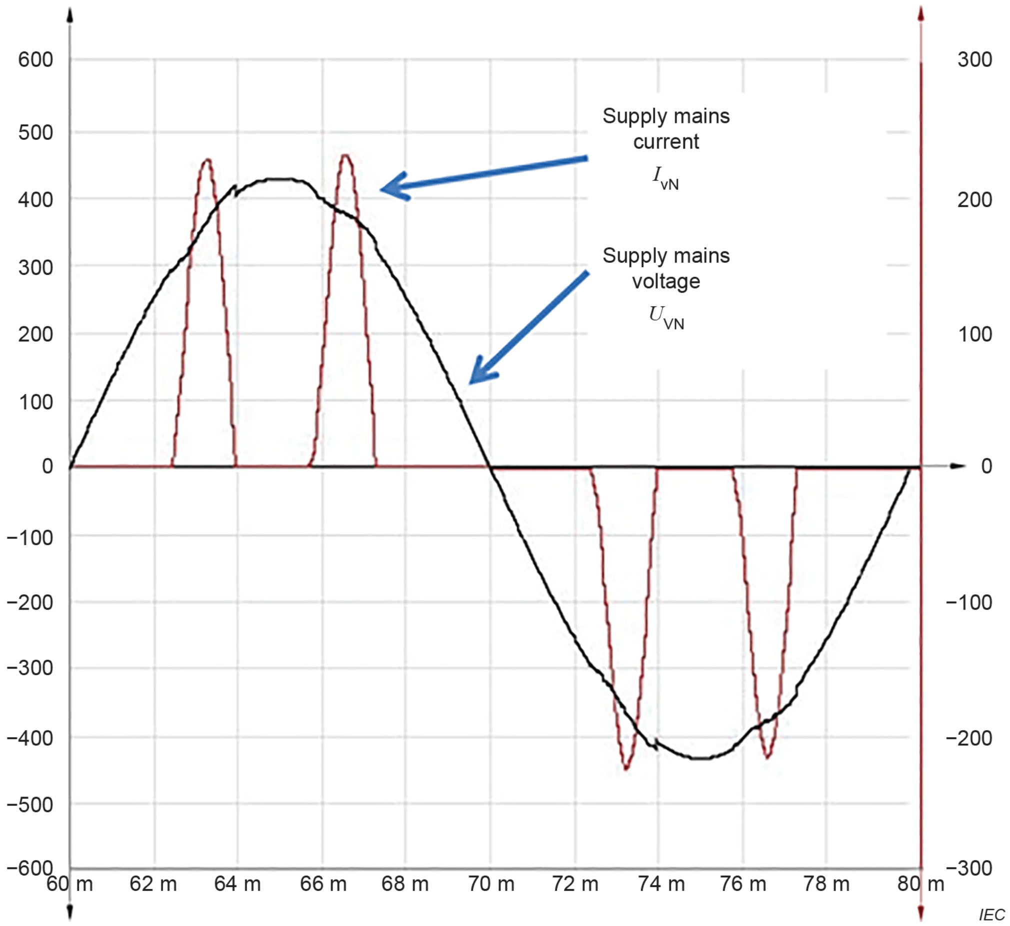


Figure B.1 – Example of distortion effect of the *input current* affected by a three-phase *converter* with capacitive load

Determination can be done by simulation, calculation or test taking into account following parameters.

- The *BDM/CDM/PDS* shall be equipped and installed to fulfil the requirement of IEC 61800-5-1 with respect to electrical safety.
- The *BDM/CDM/PDS* shall be equipped and installed according to *manufacturer's* specification with respect to electromagnetic compatibility.
- For *BDM/CDM/PDS* rated with multiple *input voltage*s, the *input voltage* shall be the lowest rated value.

- For *BDM/CDM/PDS* rated with multiple *input frequency*, the *input frequency* shall be within the specified range of the *BDM/CDM/PDS.*
- *Short-circuit ratio* R_{SC} of the supply network to the *BDM/CDM/PDS* nominal current power shall be in the range from 50 to 200 above 90 kW and in the range from 5 to 50 up to 90 kW.

NOTE Simulation or calculation can be used to determine the highest value of the *input current* based on the measured value during the test considering the maximum or minimum *short-circuit ratio* R_{SC}.

- Switching frequency and pulse pattern of the *BDM/CDM* shall be factory setting as defined by the *manufacturer* and are to be documented.
- Unless otherwise specified in case of *BDM/CDM* testing, the *BDM/CDM* shall be loaded with a *motor*
  - delivering the *rated output current* (I_{aN}/I_{AN}) of the *BDM/CDM* [A], or
  - delivering the *rated output power* (P_s) of the *motor* [kW] according to the specified *motor* type, or
  - delivering the *rated apparent output power* (S_{AN} *or* S_{aN}) of the *BDM/CDM* [kVA].
- Unless otherwise specified, the *BDM/CDM/PDS* shall be measured with shielded *motor* cable having the maximum cable length according to *manufacturer's* specification.
- The tests can be done at any ambient temperature.
- If no suitable load is available, extrapolation for the current is permitted in the range from nearly 80 % up to 100 %.
- Simulation or calculation is permitted to be used to determine the highest value of the *input current* based on the measured value during the test.

Bibliography

IEC 60027-3, *Letter symbols to be used in electrical technology – Part 3: Logarithmic and related quantities, and their units*

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

IEC 60034-14, *Rotating electrical machines – Part 14: Mechanical vibration of certain machines with shaft heights 56 mm and higher – Measurement, evaluation and limits of vibration severity*

IEC 60034-18-31, *Rotating electrical machines – Part 18-31: Functional evaluation of insulation systems – Test procedures for form-wound windings – Thermal evaluation and classification of insulation systems used in rotating machines*

IEC TS 60034-25, *Rotating electrical machines – Part 25: AC electrical machines used in power drive systems*

IEC 60034-30 (all parts), *Rotating electrical machines*

IEC 60050 (all parts), *International Electrotechnical Vocabulary (IEV)* (available at www.electropedia.org)

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

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

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

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

IEC 60076-1, *Power transformers – Part 1: General*

IEC TS 60079-42, *Explosive atmospheres – Part 42: Electrical safety devices for the control of potential ignition sources for Ex-Equipment*

IEC 60146 (all parts), *Semiconductor converters*

IEC 60204-1, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*

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

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

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

IEC 60721 (all parts), C*lassification of environmental conditions*

IEC 60721-2-6, C*lassification of environmental conditions – Part 2: Environmental conditions appearing in nature – Earthquake vibration and shock*

IEC 61131-2, *Industrial-process measurement and control – Programmable controllers – Part 2: Equipment requirements and tests*

IEC 61158 (all parts), *Industrial communication networks – Fieldbus specifications*

IEC 61378 (all parts), *Converter transformers*

IEC 61378-1, *Converter transformers – Part 1: Transformers for industrial applications*

IEC 61378-3, *Converter transformers – Part 3: Application guide*

IEC 61439-1, *Low-voltage switchgear and controlgear assemblies – Part 1: General rules*

IEC 61800-1, *Adjustable speed electrical power drive systems – Part 1: General requirements – Rating specifications for low voltage adjustable speed d.c. power drive systems*

IEC 61800-4:2002, *Adjustable speed electrical power drive systems – Part 4: General requirements – Rating specifications for a.c. power drive systems above 1 000 V a.c. and not exceeding 35 kVEN 50325-4, Industrial communications subsystem based on ISO 11898 (CAN) for controller-device interfaces – Part 4: CANopen*

EN 50598-3, *Ecodesign for power drive systems, motor starters, power electronics and their driven applications – Part 3: Quantitative eco design approach through life cycle assessment including product category rules and the content of environmental declarations*

UL 10001-1, *Product Category Rules (PCR). For preparing an Environmental Product Declaration (EPD) for the Product Category: Power Inverter Products*

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