

Australian Standard[®]

Adjustable speed electrical power drive systems

Part 1: General requirements—Rating specifications for low voltage adjustable speed d.c. power drive systems



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 - Australian Electrical and Electronic Manufacturers Association
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 - Monash University
-

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Adjustable speed electrical power drive systems

Part 1: General requirements—Rating specifications for low voltage adjustable speed d.c. power drive systems

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PREFACE

This Standard was prepared by the Standards Australia Committee EL-027, Power Electronics.

The objective of this Standard is to provide designers, manufacturers, specifiers, purchasers and users of variable speed drive systems with a set of characteristics to define variable speed d.c. drives.

This Standard is identical with, and has been reproduced from IEC 61800-1, Ed.1.0 (1997), *Adjustable speed electrical power drive systems—Part 1: General requirements—Rating specifications for low voltage adjustable speed d.c. power drive systems*.

As this Standard is reproduced from an International Standard, the following applies:

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The terms 'normative' and 'informative' are used to define the application of the annex to which they apply. A normative annex is an integral part of a standard, whereas an informative annex is only for information and guidance.

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STANDARDS AUSTRALIA

Australian Standard

Adjustable speed electrical power drive systems
Part 1: General requirements—Rating specifications for low voltage
adjustable speed d.c. power drive systems

1 General**1.1 Scope and object**

This part of IEC 61800 applies to general purpose adjustable speed d.c. drive systems which include the power conversion, control equipment, and also a motor or motors. Excluded are traction and electrical vehicle drives.

It applies to power drive systems (PDS) connected to line voltages up to 1 kV a.c., 50 Hz or 60 Hz.

EMC aspects are covered in IEC 61800-3.

This part of IEC 61800 gives the characteristics of the converters and their relationship with the complete d.c. drive system. It also states their performance requirements with respect to ratings, normal operating conditions, overload conditions, surge withstand capabilities, stability, protection, a.c. line earthing, and testing. Furthermore, it deals with application guidelines, such as control strategies, diagnostics, and topologies.

This part of IEC 61800 is intended to define a complete d.c. PDS in terms of its performance and not in terms of individual subsystem functional units.

1.2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 61800. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 61800 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

References to international standards that are struck through in this clause are replaced by references to identical Australian Standards that are listed immediately thereafter and identified by shading.

~~IEC 60034-1:1994, Rotating electrical machines—Part 1: Rating and performance~~

AS 1359.101, *Rotating electrical machines—General requirements, Part 101: Rating and performance* (identical to IEC 60034-1:1996)

IEC 60034-2: 1972, *Rotating electrical machines – Part 2: Methods for determining losses and efficiency of rotating electrical machinery from tests (excluding machines for traction vehicles)*

~~IEC 60034-9:1990, Rotating electrical machines—Part 9: Noise limits~~

AS 1359.109, *Rotating electrical machines—General requirements, Part 109: Noise limits*

~~IEC 60038:1983, IEC standard voltages~~

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AS 60038, *Standard voltages*

IEC 60050 (111):1996, *International electrotechnical vocabulary (IEV) – Chapter 111: Physics and chemistry*

~~IEC 60050 (151):1978, *International electrotechnical vocabulary (IEV) – Chapter 151: Electrical and magnetic devices*~~

AS 1852.151, *International electrotechnical vocabulary, Part 151: Electric and magnetic devices (identical to IEC 60050(151):1978)*

~~IEC 60050 (441):1984, *International electrotechnical vocabulary (IEV) – Chapter 441: Switchgear, controlgear and fuses*~~

AS 1852.441, *International electrotechnical vocabulary, Part 441: Switchgear, controlgear and fuses (identical to IEC 60050(441):1984)*

IEC 60050 (551): *International electrotechnical vocabulary (IEV) – Chapter 551: Power electronics*

~~IEC 60050 (601):1985, *International electrotechnical vocabulary (IEV) – Chapter 601: Generation, transmission and distribution of electricity – General*~~

AS 1852.601, *International electrotechnical vocabulary, Part 601: Generation, transmission and distribution of electricity—General (identical to IEC 60050(601):1985)*

IEC 60076, *Power transformers*

~~IEC 60146-1-1:1991, *Semiconductor converters. Common specifications and line commutated converters—Part 1-1: Specification of basic requirements*~~

AS 60146.1.1, *Semiconductor converters, Part 1.1: General requirements and line commutated converters—Specifications of basic requirements (identical to IEC 60146-1-1:1991)*

~~IEC 60146-1-2:1991, *Semiconductor converters. Common specifications and line commutated converters—Part 1-2: Application guide*~~

AS 60146.1.2, *Semiconductor converters, Part 1.2: General requirements and line commutated converters—Application guide (identical to IEC 60146-1-2:1991)*

~~IEC 60146-1-3:1991, *Semiconductor converters. Common specifications and line commutated converters—Part 1-3: Transformers and reactors*~~

AS 60146.1.3, *Semiconductor converters, Part 1.3: General requirements and line commutated converters—Transformers and reactors (identical to IEC 60146-1-3:1991)*

IEC 60204-1:1992, *Electrical equipment of industrial machines – Part 1: General requirements*

IEC 60364-4-41: 1992, *Electrical installations of buildings of buildings – Part 4: Protection for safety – Chapter 41: Protection against electric shock*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP code)*

IEC 60664-1:1992, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60721-3-1: 1987, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities. Storage*

IEC 60721-3-2:1997, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities. 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 61000-2-4:1994, *Electromagnetic compatibility (EMC) – Part 2: Environment – Section 4: Compatibility levels in industrial plants for low frequency conducted disturbances*

~~IEC 61000-4-7:1991, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 7: General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto*~~

AS 61000.4.7, *Electromagnetic compatibility (EMC), Part 4.7: Testing and measurement techniques—General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto*

IEC 61136-1:1992, *Semiconductor power convertors – Adjustable speed electric drive systems – General requirements – Part 1: Rating specifications, particularly for d.c. motor drives*

~~IEC 61800-3:1996, *Adjustable speed electrical power drive systems – Part 3: EMC product standard including specific test methods*~~

AS 61800.3, *Adjustable speed electrical power drive systems - EMC requirements and specific test methods*

IEC guide 106:1989, *Guide for specifying environmental conditions for equipment performance rating*

1.3 Symbols

Table 1 lists symbols defined and/or used in this part of IEC 61800.

Table 2 lists symbols and units for motor parameters.

Table 1 – Symbols

Parameter	Symbol	Unit	Definition
Rated system voltage	U_{LN}	V	2.4.1
Rated system frequency	f_{LN}	Hz	2.4.2
Line-side converter rated a.c. voltage	U_{VN}	V	2.4.3
Line-side rated a.c. current of the CDM/BDM	I_{LN}	A	2.4.4
Rated input current of the converter	I_{VN}	A	2.4.5
Line-side harmonic content	H_L	V ou A	2.4.6
Line-side total harmonic distortion	THD	%	2.4.8
Converter input displacement factor	$\cos \phi_{V1}$		2.4.9
Line-side displacement factor	$\cos \phi_{L1}$		2.4.10
Input total power factor	λ_L		2.4.11
Maximum a.c. system, symmetrical short-circuit current	I_{SCM}	A	2.4.12
Short-circuit ratio	R_{SC}		2.4.12
DC current	I_d	A	2.5.1
Rated continuous output current	I_{dN}	A	2.5.2
Overload output current (overload capability)	I_{dM}	A	2.5.3
Rated output voltage	U_{dN}	V	2.5.5
Voltage ripple content	U_{pp}	V	2.5.6
Current ripple content	I_{pp}	A	2.5.6
Efficiency of drive system	η_D	%	2.5.8
Efficiency of CDM	η_C	%	2.5.8
Base speed	N_0	r/min	2.7.3
Maximum operating speed	N_M	r/min	
Minimum operating speed	N_{min}	r/min	
Maximum safe motor speed	N_{smax}	r/min	2.7.4
Torque	M	Nm	
Inertia	J	kgm ² or Nms ²	

Table 2 – Symbols for motor parameters

Parameter	Symbol	Unit
Rated output power	P_N	kW
Rated armature voltage	U_{AN}	V
Rated armature current	I_{AN}	A
Peak load current value	I_p	A
Allowable rate of change of the armature current	dI_A/dt	As^{-1}
Allowable ripple of the armature current	I_{ppM}	A
Armature inductance	L_A	H
Armature resistance	R_A	Ω
Rated hot field voltage	U_{FN}	V
Rated field current	I_{FN}	A
Field current for maximum speed	I_{FNm}	A
Field inductance	L_F	H
Field resistance	R_F	Ω
Base speed	N_0	r/min (note 1)
Maximum speed	N_M	r/min
Maximum safe motor speed	N_{smax}	r/min
Torque (note 2)	M	Nm
Inertia	J	kgm^2 or Nms^2
NOTE 1 – Practically, speed is expressed in RPM as well.		
NOTE 2 – Torque/speed characteristics: see A.5.1.		

2 Definitions

For the purpose of this part of IEC 61800, the following definitions, as well as those given in IEC 60050 (111), IEC 60050 (151), IEC 60050 (441), IEC 60050 (551), IEC 60050 (601), IEC 60146-1-1, IEC 60146-1-2, IEC 60146-1-3, and IEC 61136-1 apply.

2.1 System

2.1.1

d.c. power drive system (PDS) (see figure 1)

system consisting of power equipment (composed of converter section, d.c. motor and other equipment such as, but not limited to, the feeding section or the field supply), and control equipment (composed of switching control – on/off for example – speed control, current control, firing system, field control, protection, status monitoring, communication, tests, diagnostics, process interface/port, etc.)

NOTE – Figure 1 illustrates the main functional elements of a d.c. drive system. It also includes equipment which may be optional on many drive systems. It is intended to encompass a wide variety of d.c. drive configuration possibilities. The converter section does not illustrate or imply a specific topology, or type of switching device, due to the wide variety of both in current use. See annex F.

2.1.2

d.c. power drive system – hardware configuration

PDS which consists of a complete drive module (CDM) and a motor or motors with sensors which are mechanically coupled to the motor shaft (the driven equipment is not included). See figure 2 for hardware partition of the power drive system

NOTE – Figure 2 illustrates the parts of equipment which can be grouped and supplied as defined and shown.

2.1.2.1

basic drive module (BDM)

drive module which consists of, a converter section, a control equipment for speed, torque, current or voltage, and a power semiconductor gating system, etc.

2.1.2.2

complete drive module (CDM)

drive system, without the motor and the sensors which are mechanically coupled to the motor shaft, consisting of, but not limited to, the BDM, and extensions such as feeding section, field supply, and auxiliaries

2.1.2.3

installation

equipment or equipments which include at least both the PDS and the driven equipment

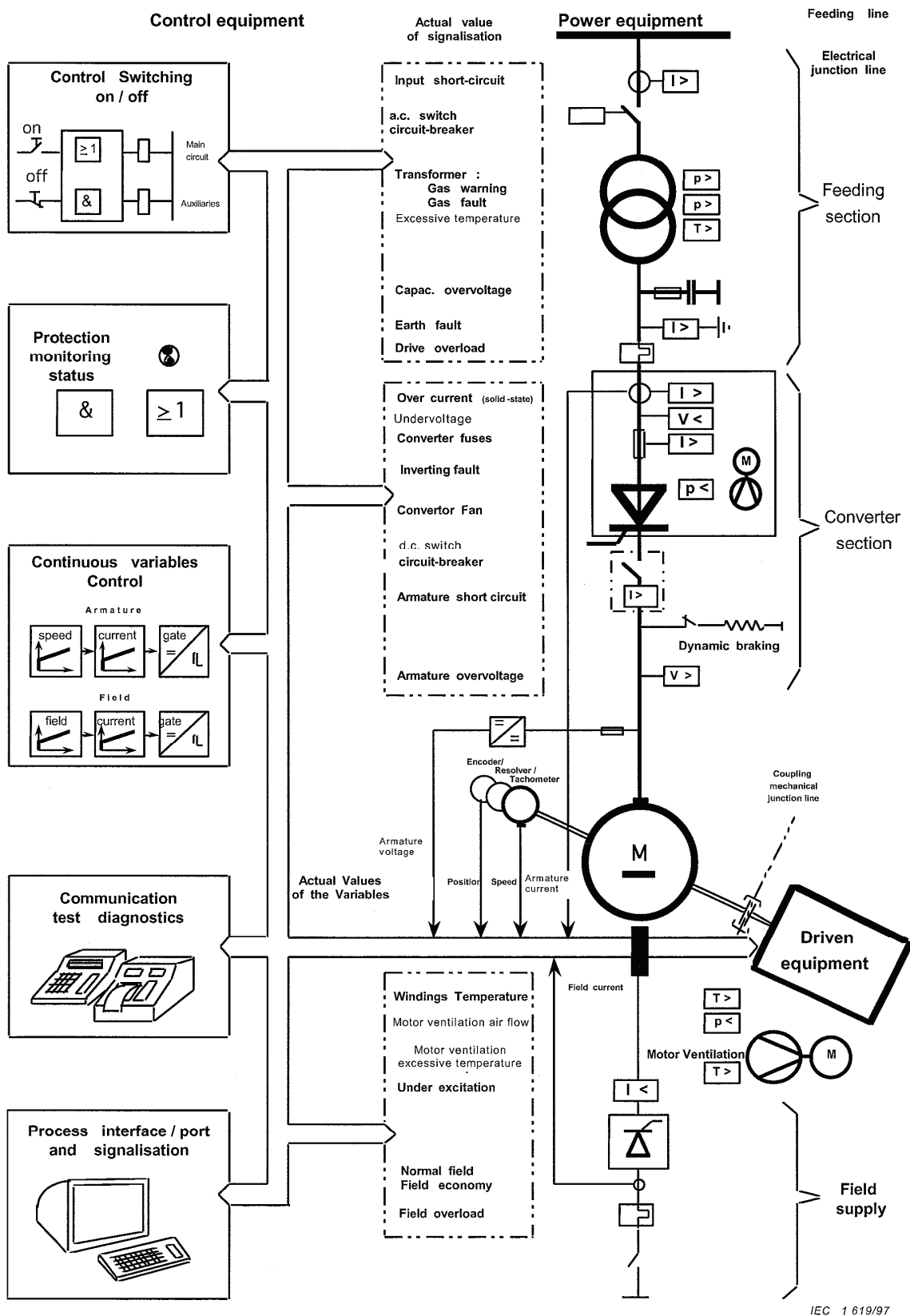
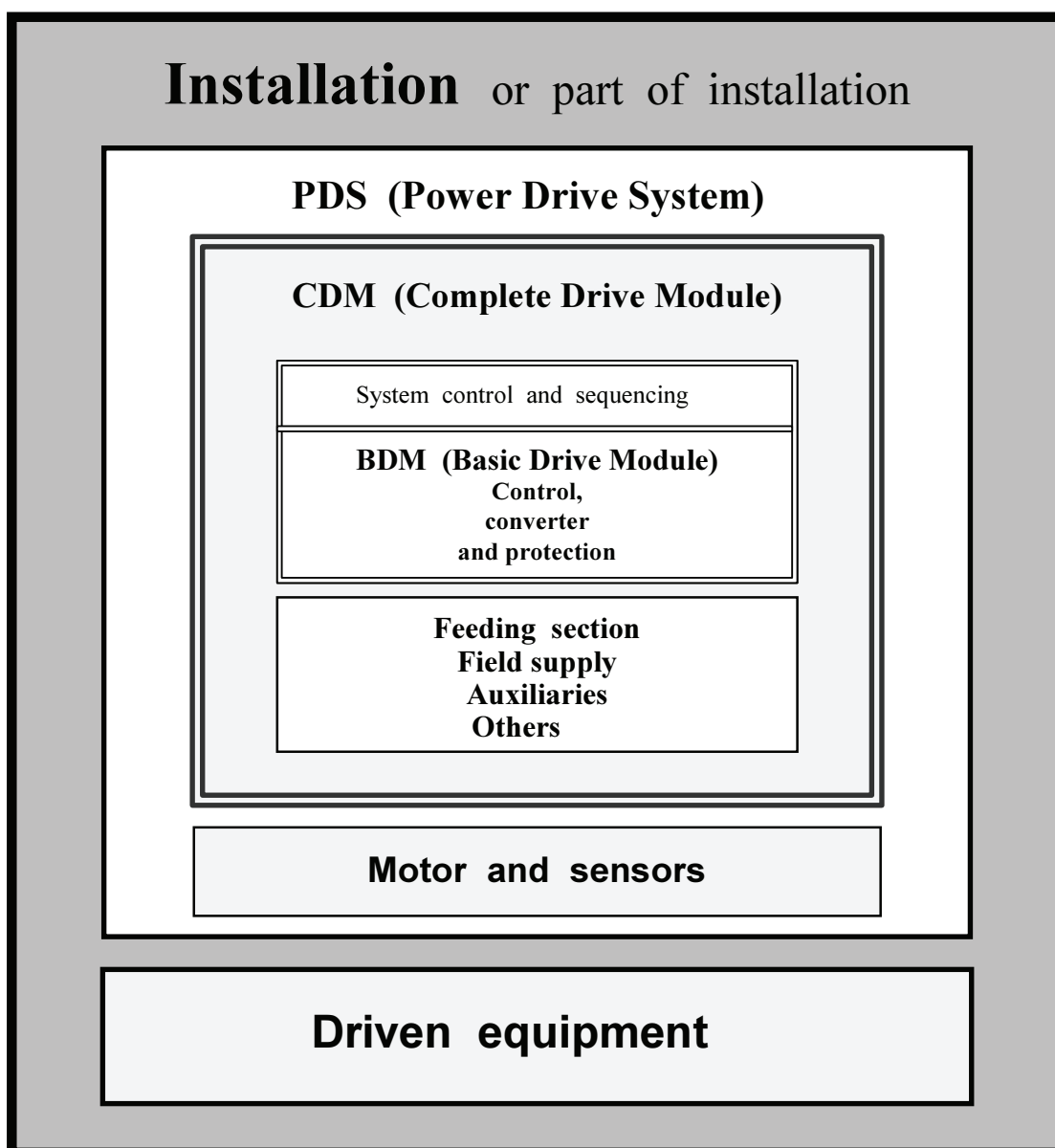


Figure 1 – Function diagram of a d.c. – drive system



IEC 1 620/97

Figure 2 – PDS hardware configuration within an installation

2.2 Converters

2.2.1

converter, general purpose

operating unit for electronic power conversion, changing one or more electrical characteristics and comprising one or more electronic switching devices and associated components, such as transformers, filters, commutation aids, controls, protections and auxiliaries, if any

2.2.2

rectifying – rectification

converter action converting from a.c. to d.c. The rectifier can be uncontrolled or controlled [IEV 551-11-06 modified]

NOTE – For the purpose of this part of IEC 61800, the line-side converter normally operates as a rectifier.

2.2.3

inverting – inversion

converter action converting from d.c. to a.c. [IEV 551-11-07 modified]

NOTE – For the purpose of this part of IEC 61800, the line-side converter sometimes operates as an inverter.

2.2.4**converter, d.c. linked**

converter comprising a rectifier and a chopper with an intermediate d.c. link

2.2.5**converter, line-side commutated**

converter in which the commutation voltages are supplied by the a.c. input

2.2.6**chopper**

converter operating a d.c. conversion (d.c. to d.c.) by means of electronic devices using forced commutation. Its output delivers adjustable d.c. voltage [IEV 551-12-28 modified]

NOTE – In this part of IEC 61800, forced commutation refers to deliberate extinction of semiconductor device before commutation can take place at zero current (natural commutation).

2.2.7**converter, voltage source**

converter which provides an adjustable output voltage supply, essentially unaffected by the value of the load

NOTE – The term “voltage stiff a.c./d.c converter” having a similar physical background is used in the second edition of IEC 50(551).

2.3 Drive system operating characteristics**2.3.1****two quadrant operation**

converter operation of a machine as a motor in one direction of machine rotation and as a generator in the opposite direction of rotation. It involves operation in quadrant I and II of the torque/speed diagram (see figure 3)

2.3.2**four quadrant operation**

converter operation of a machine as either a motor or a generator in either direction of machine rotation. It involves operation in quadrants I, II, III & IV of the torque / speed diagram as shown in figure 3

NOTE – Concerning the combinations of current flow and voltage direction, see figures 1, 2 and 3 of IEC 61136-1, where voltage and current axis have been inverted (current corresponding to torque, and voltage to speed).

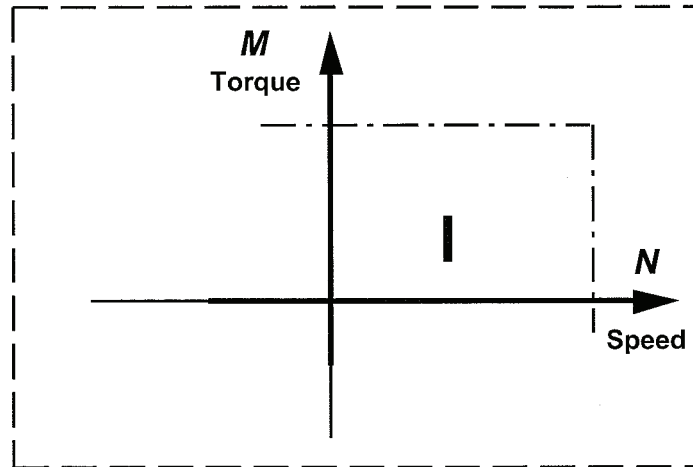
2.3.3**dynamic braking**

process of converting the rotational energy of the armature and connected inertial load to electrical energy dissipated in a resistance

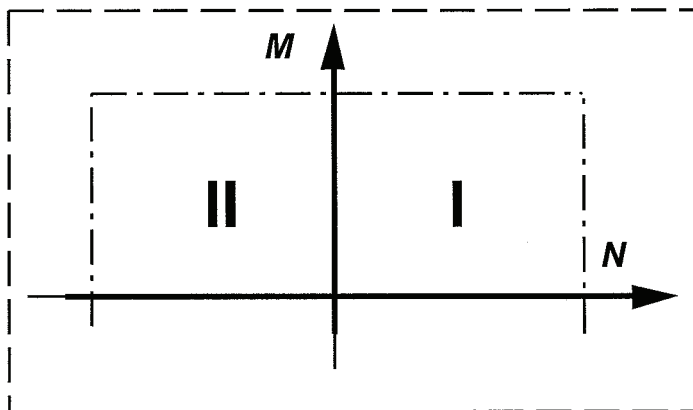
2.3.4**regeneration**

process of converting the mechanical energy of the system to electrical energy and transferring it to the input supply. The motor is then working as a generator and the ratings of the motor may be different

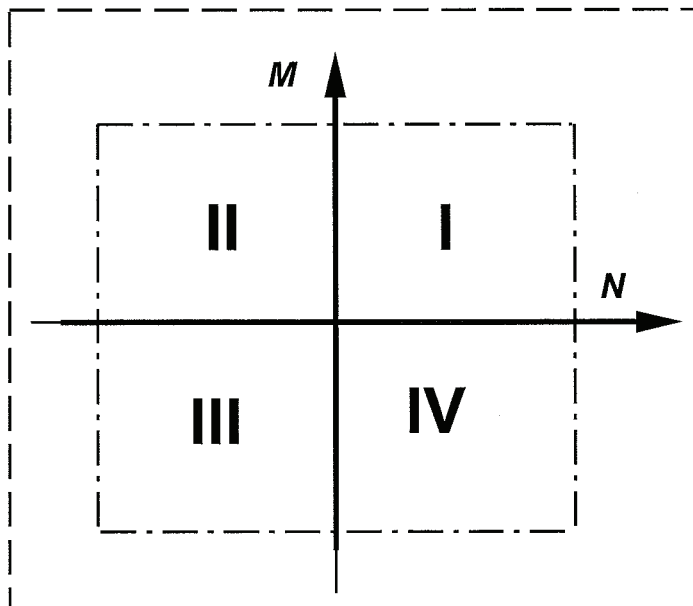
**One
quadrant**



**Two
quadrants**



**Four
quadrants**



IEC 1 621/97

Figure 3 – Operating quadrants

2.4 CDM, BDM and converter input parameters

Symbols defined in 2.4 are included in table 1.

2.4.1

rated system voltage U_{LN}

RMS input line-to-line voltage at the supply terminals of the customers installation to which the PDS will be connected

2.4.2

rated system frequency f_{LN}

frequency in Hertz of the power input system alternating voltage

2.4.3

line-side rated a.c. voltage U_{VN}

rated r.m.s. line-to-line input voltage at the a.c. terminals of the line-side converter, which has been designated as the basis for the converter rating

NOTE – This voltage may differ from the rated system voltage U_{LN} due to the use of transformers and the effect of impedance. Some drives may have an input transformer with primary voltage higher than 1 000 V. In this case, the transformer and protective devices have to meet this standard and other relevant IEC standards. Capacitively coupled high voltage from primary to secondary winding must be bypassed to earth (see annex B).

2.4.4

line-side rated a.c. current I_{LN}

maximum r.m.s. value of current on the line-side of the CDM/BDM under rated conditions. 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

NOTE – This current includes currents supplied to the auxiliary circuits of the CDM/BDM. It takes into account the effect of d.c. current ripple and circulating current, if any.

2.4.5

rated input current I_{VN}

maximum r.m.s. value of current on the valve side of the converter under rated conditions. 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

2.4.6

line-side harmonic content

quantity obtained by subtracting from an alternating quantity its fundamental component [IEV 551-07-04, applied to the line-side of the system]

NOTE – For example, for voltage (from a practical approach and with interharmonics neglected), the r.m.s. value of the harmonic content is

$$U_{Hn} = \left(\sum_{h=2}^{h=n} U_h^2 \right)^{0.5}$$

2.4.7

characteristic current harmonics

orders of the current harmonics produced by converter equipment in the course of normal operation. For example, in a 6-pulse converter the characteristic current harmonics are the non triple, odd harmonics: $h = 6k \pm 1$ (k any integer)

NOTE – In addition to power system frequency harmonics, there can be other harmonics resulting from interaction with the converter load. They are called interharmonics.

2.4.8

harmonic distortion

according to common practice, the total harmonic distortion coefficient is relative to the fundamental component of the quantity which is considered. The harmonic factor is relative to the r.m.s. value of the quantity which is considered [IEV 551-17-05 and IEC 551-17-06, modified]

THD and THF are defined by:

$$THD = \frac{\sqrt{Q^2 - Q_1^2}}{Q_1} \quad \text{and} \quad THF = \frac{\sqrt{Q^2 - Q_1^2}}{Q}$$

where

Q_1 is the r.m.s. value of the fundamental;

Q is the total r.m.s. value;

h is the harmonic order;

Q_h is the r.m.s. value of harmonic component of order h ;

Q can represent either current or voltage.

For the purpose of this standard and for clarity, limits are referred to the corresponding rated value.

Limits for THD and THF are defined by:

$$THD = \frac{\sqrt{Q^2 - Q_{1N}^2}}{Q_{1N}} \quad \text{and} \quad THF = \frac{\sqrt{Q^2 - Q_{1N}^2}}{Q_N}$$

NOTE 1 – These definitions are in accordance with the second edition of IEC 551 and with common practice. The network voltage waveform is much less distorted than the injected current. Therefore, application of both definitions, total harmonic distortion coefficient THD or total harmonic factor THF, to the voltage provides the same result while the difference is significant when current is considered.

NOTE 2 – It is important to note that these definitions include interharmonics. When interharmonics are present the wave form is no longer periodical, which can produce more complex effects than those produced by harmonics. If interharmonics are negligible, these equations simplify to:

$$THD = \frac{\sqrt{\sum_{h=2}^{h=40} Q_h^2}}{Q_{1N}} \quad \text{and} \quad THF = \frac{\sqrt{\sum_{h=2}^{h=40} Q_h^2}}{Q_N}$$

where

Q_{1N} is the rated r.m.s. value of the fundamental;

Q_N is the rated total r.m.s. value.

The summation is extended to and includes order 40, according to IEC common practice.

NOTE 3 – For particular use, the highest frequency content of THD (order h from 14 to 40 inclusive) is named partial harmonic distortion coefficient PHD, and the even content (where order h is only even) is named even harmonic distortion coefficient EHD. Applied to current this gives:

$$PHD = \frac{\sqrt{\sum_{h=14}^{h=40} I_h^2}}{I_{1N}} \quad \text{and} \quad EHD = \frac{\sqrt{\sum_{h=2, \text{even}}^{h=40} I_h^2}}{I_{1N}}$$

2.4.9

converter input displacement factor $\cos \phi_{V1}$

cosine of the phase displacement angle between the fundamental phase components of the voltage and current on the input a.c. side of the input power converter

2.4.10

line-side displacement factor $\cos \phi_{L1}$

cosine of the phase displacement angle between the fundamental phase components of the voltage and current on the input a.c. side of the CDM

2.4.11**input total power factor, λ_L**

ratio of the total power input, to the apparent power, as determined at the connection of the CDM to the supply

Example: in a three-phase system where the voltage is considered sinusoidal.

$$\begin{aligned}\lambda_L &= (U_L I_{L1} \sqrt{3} \cos \varphi_{L1}) / (U_L I_L \sqrt{3}) \\ &= (I_{L1} / I_L) \times \cos \varphi_{L1}\end{aligned}$$

NOTE 1 – The power factor includes the effect of displacement $\cos \varphi_1$ and of harmonics by means of the deformation factor $\nu = \lambda / \cos \varphi$.

NOTE 2 – The definition applies to the converter input (subscript V) or to the CDM input line-side (subscript L).

2.4.12**maximum allowable a.c. system, symmetrical short-circuit current I_{SCM}**

maximum allowable symmetrical short-circuit current (I_{SCM}), as specified on the rating plate can be related to the fundamental component of the line-side rated a.c. current (I_{LN1}) by means of the short-circuit ratio (R_{SC})

R_{SC} is the ratio of the short-circuit power of the source to the fundamental apparent power on the line-side of the converter(s). (See IEC 60146-1-1.)

$$R_{SC} = S_{SC} / S_{LN1} = I_{SC} / I_{LN1}$$

The maximum allowable symmetrical short-circuit current (I_{SCM}) is of importance in the definition of the protection of the converter. At the point of common coupling (PCC), the relative short-circuit power shall be considered (see 1.5.35 of IEC 60146-1-1). This R_{SC} has to be limited to the following R_{SCM} :

$$R_{scm} = I_{SCM} / I_{LN1}$$

where I_{LN1} is equal to the fundamental content of I_{LN} .

2.5 CDM, BDM and converter output parameters

Symbols defined in 2.5 are included in table 1.

2.5.1**d.c. current I_d**

average value of the current in the d.c. link over one full period of the input power system frequency

NOTE – DC current I_d can also indicate the current of the intermediate d.c. link in the case of an indirect converter using a chopper. Generally I_A is used to indicate the output current which is also the motor current.

2.5.2**rated continuous output current I_{dN}**

output current which can be supplied continuously without exceeding established limits, under prescribed operating conditions

NOTE – IEC 61136-1 gives different classes of rated current for complex cases of load duty.

2.5.3**overload capability I_{dM}**

maximum output current which can be supplied for a specified period of time, without exceeding established limits under prescribed operating conditions

2.5.4**continuous output rating P_{dN}**

active power which a converter is capable of supplying to a load continuously without exceeding established limits

2.5.5**rated output voltage U_{dN}**

specified value at rated d.c. current of the direct voltage between d.c. terminals of the CDM/BDM. This value is the available mean value of the d.c. voltage under usual service conditions, as specified in clause 4

2.5.6**ripple U_{pp} , I_{pp}**

periodic a.c. voltage/current superimposed on steady direct voltage/current, usually expressed as peak-to-peak value. If the ripple content of the current is given as peak-to-peak value in amperes measured or calculated at rated voltage of the motor, then the symbol is I_{ppN}

NOTE – Current ripple is also given as a ratio $r = I_{pp} / I_d$, where I_d is the mean value of output current (see B.4.3.2), but $r/2$ is often used in the definition of the motor parameters. It is important to clarify which ratio is used.

2.5.7**load-side harmonic content**

function obtained by subtracting the d.c. component from the non-sinusoidal periodic function on the output side of the converter. For example, the r.m.s. value of the current harmonic content is

$$I_{dHn} = \left(\sum_{h=2}^{h=n} I_h^2 \right)^{0.5}$$

In practice n is limited to 40.

2.5.8**efficiency of power conversion η_D , η_C**

efficiency η_D of the drive system is the ratio of the power delivered by the motor shaft to the total power drawn from the input power supply (see feeding line in figure 1), and is usually expressed as a percentage. Efficiency of the CDM (complete drive module) η_C is the ratio of the total output power delivered by the CDM to armature, field, and auxiliaries (motor ventilation fan, etc.) to the total power drawn from the input power supply (see feeding line in figure 1), and is usually expressed as a percentage

2.5.9**maximum field supply current I_{FM}**

maximum continuous mean current of the motor field load that the field converter can supply

NOTE – If an uncontrolled field converter is used, the converter has to be sized for the maximum field current, with a cold motor.

2.5.10**rated field supply voltage U_{FN}**

rated mean voltage of the motor field load to be connected to the field converter

2.6 Converter circuitry and circuit elements**2.6.1****commutating capacitor**

capacitor which provides commutating energy for self-commutated thyristors in a self-commutated chopper

2.6.2**commutating inductor**

inductor having one or more windings which modifies or couples the transient current produced during commutation

2.6.3**a.c. filter network**

network designed to reduce the flow of harmonic currents into the associated power system

2.6.4**power factor correction network**

network designed to improve the power factor of the associated power system. This network will frequently also reduce the flow of harmonic currents

2.6.5**d.c. filter capacitor**

capacitor connected across the rectifier output within a converter to reduce voltage ripple

2.7 Motors**2.7.1****d.c. motor types**

DC motors are typically equipped with separate field (see figure 1). This type of motor can be compensated or not. The purpose of compensation is to minimize the armature reaction and increase the motor commutating ability.

NOTE – Other types of motors are: permanent magnet motor, series field, combinations (shunt and series).

2.7.2**rated hot field voltage**

rated field voltage at operational temperature

2.7.3**base speed N_0**

speed obtained with rated armature voltage, with rated armature current and rated field current, usually the breakpoint speed between constant torque and constant power operation

2.7.4**maximum safe motor speed**

maximum designed speed of the motor under which no permanent abnormal mechanical deformation or weakness is introduced (see clause 21 of IEC 60034-1)

NOTE – The maximum safe speed of the driven equipment may be more restrictive.

2.7.5**torque pulsation**

cyclic fluctuation of a steady-state motor torque measured as a peak-to-peak variation

2.8 Control systems**2.8.1****controlled variable**

system variable in the feedback control of adjustable d.c. drives. Some examples of controlled variables are speed, armature voltage, armature and field current

2.8.2**service variable**

specified variable, usually related to ambient conditions (e.g. temperature), for which the feedback control system is to correct in attempting to maintain the ideal value of the controlled variable

2.8.3**operating variable**

specified variable (e.g. load torque for a speed controlled drive) other than those arising from service conditions and drift for which the feedback control system is to correct in attempting to maintain the ideal value of the controlled variable

2.8.4**feedback control system variables**

range of service and operating variables covering the total deviations for which the feedback system attempts to correct by means of the controlled variables. The accuracy of this control is then defined as the width of the band of allowable deviation within which the feedback system will regulate the controlled variable

3 Functional features**3.1 Operational**

CDM shall include specified features which may include, but are not limited to, one or more of the following features:

- timed acceleration;
- timed deceleration;
- jog;
- adjustable current limit(s);
- dynamic braking;
- reversing;
- regeneration;
- line filtering;
- input/output data processing (analog/digital);
- automatic restart.

3.2 Fault supervision

The CDM shall provide specified fault indication. 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 CDM faults which may include but are not limited to the following:

- external faults;
- fuse(s) blown;
- instantaneous overcurrent;
- overtemperature (converter);
- loss of cooling air;
- motor overload;
- auxiliary power supply fault;
- supply over/undervoltage;
- supply phase loss;
- motor overvoltage;
- overspeed and/or tachometer loss protection;
- field loss protection;
- internal control system fault;
- regulator/power circuit diagnostics.

3.3 Minimum status indication required

The CDM shall be equipped with status indication signals for “drive on” (whether rotating or at standstill). The CDM may also be equipped with a status indication signal “drive ready for operation”.

3.4 I/O devices

Number and nature of I/O shall be stated by the manufacturer. Any modification shall be agreed upon between the manufacturer and user.

NOTE – 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 communicated through serial or parallel links according to various communication standards. Both analog and digital variables can be manually set by use of a control panel and can be read on displays. Variables and parameters are treated in the same manner.

4 Service conditions

4.1 Installation and operation

Unless modified, the equipment which is within the scope of this part of IEC 61800 shall be capable of operation under the conditions listed in 2.2 and 2.3 of IEC 60146-1-1, and IEC Guide 106.

4.1.1 Electrical service conditions

Unless otherwise specified, the CDM or BDM shall be designed to operate under the service conditions specified below. The values specified include the effect of the drive system being considered.

EMC requirements for power drive systems are stated in IEC 61800-3.

NOTE – The limits specified in 4.1.1.1 to 4.1.1.5 link the EMC standards to existing practice in semiconductor converters given in 2.5.1, 2.5.2 and 2.5.3 of IEC 60146-1-1, and correspond generally to class B.

4.1.1.1 Frequency variations

Frequency $f_{LN} \pm 2\%$ ($\pm 4\%$ for separated supply network) according to class 3 defined in IEC 61000-2-4.

Rate of change of frequency $\leq 2\% f_{LN}/s$.

(See also 5.2.3.2 of IEC 61800-3.)

4.1.1.2 Voltage changes

Voltage limits for uninterrupted operation

PDS rated input voltage $\pm 10\%$ (at the point of coupling PC), according to class 2 defined in IEC 61000-2-4 (see also 5.2.2.1 and 5.2.2.2 of IEC 61800-3).

NOTE – Short time voltage variation beyond the levels specified may result in interruption of operation or tripping. If continuous operation is necessary, an agreement is required between the user and the supplier/manufacturer.

Voltage limits for rated performance

Rated converter performance shall be maintained when the steady-state fundamental component of the line a.c. supply voltage is equal to or greater than 100 % and equal to or less than 110 % of the rated value measured at the terminals of the BDM. Rated operation at voltages below 100 % of rated voltage shall be subject to agreement between the user and the supplier/manufacturer.

NOTE – Also refer to 5.2.1.

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4.1.1.3 Voltage unbalance

PDS shall operate with a line voltage unbalance (at the point of coupling PC) up to, but not exceeding 3 % of the fundamental rated input voltage (U_{LN1}). See 5.2.3.1 and B.3 of IEC 61800-3, for definition and calculation.

4.1.1.4 Source impedance

The minimum R_{SC} ratio for the PDS to meet rated performance shall be 20 determined at the point of coupling (PC).

NOTE 1 – A larger source impedance may cause snubbers to have a poor damping ratio resulting in possible failure condition and excessive notch size.

NOTE 2 – See the manufacturer's documentation to determine the maximum design R_{SC} ratio.

4.1.1.5 Harmonics and commutation notches

a) Harmonics

Unless otherwise agreed to, the equipment within the scope of this part of IEC 61800 shall be designed to operate with a voltage total harmonic distortion (THD) of 10 % under steady-state conditions (at the point of coupling, PC), and of 15 % during transient periods of less than 15 s, according to class 3 defined in IEC 61000-2-4 (see also 5.2.1 of IEC 61800-3).

NOTE – Compatibility levels for individual harmonic voltages are given in tables 3, 4 and 5 of IEC 61000-2-4.

A theoretical example of harmonic distortion illustrates, in annex B.5, a practical assessment of the relationship between emission and immunity, to take into account the effect of the drive itself as stated in 4.1.

b) Commutation notches

The equipment shall meet the rated performance with the following notching limits at the line-side terminals of the CDM/BDM (See 2.5.4.1 of IEC 60146-1-1, immunity class B).

- Commutation notch depth 40 % of U_{LWM}
- Commutation notch area 250 % × degrees

4.1.1.6 Repetitive and non-repetitive transients

A typical a.c. voltage waveform containing repetitive and non-repetitive transients is shown in figure 4.

The transients are caused by converter commutation, switching on the network and disturbances on the power system.

The BDM shall be designed to operate in an environment with non-repetitive transients caused by transformer switching provided that the supply transformer is sized for no more than five times the apparent power of the drive under consideration. Where transformers are sized for greater capacity, additional transient energy absorption capacity shall be provided external to the BDM.

The energy E (in joules) of the non-repetitive transient caused by switching of the transformer is directly related to the magnetisation energy of the transformer feeding the BDM. The energy can be calculated by the equation:

$$E = 400 \times S_N$$

where S_N is expressed in MVA and is equal to:

$$S_N = \sqrt{3} \times U_{LN} \times I_{LN} \times 10^{-6}$$

where

U_{LN} is the rated system voltage;

I_{LN} is the line-side rated a.c. current.

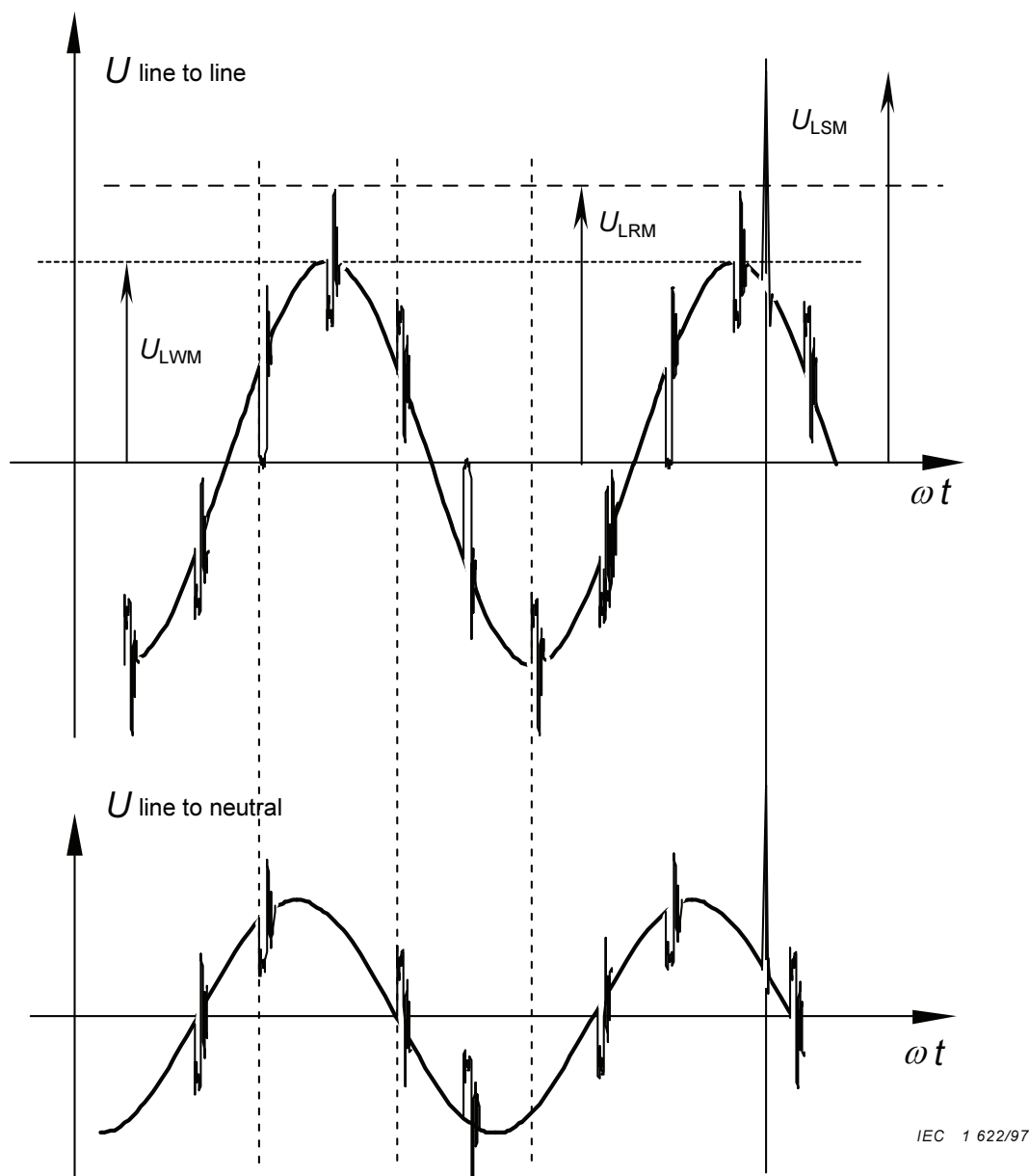
The following assumptions are made:

- the magnetization current is 5 %;
- switching occurs at the point of maximum energy release.

NOTE – If the transformer characteristics are known, a specific calculation can be made.

4.1.1.7 Unusual conditions

Particular conditions such as unusual operating duty, unbalanced a.c. system impedance, unusually strong magnetic fields, unusually high levels of radio frequency interference (such as from communication transmitters), and additional impedance outside the CDM or BDM added after the acceptance test shall be communicated where known or specified.



NOTE – Typical range of per unit values are provided for reference only. The figure assumes there is no impedance between PDS terminals and the converter.

Repetitive transients (U_{LRM}/U_{LWM}): 1,25 to 1,50, depending on the snubber design with respect to di/dt and IRR.

Non repetitive transients (U_{LSM}/U_{LWM}): 1,80 to 2,50, depending on additional protective devices.

Figure 4 – Typical a.c. voltage waveform at six pulses converter terminals

4.1.2 Environmental service conditions

4.1.2.1 Climatic conditions

The CDM shall operate under environmental conditions specified in IEC 60721-3-3 for class 3K3, and section 2 of IEC 60146-1-1 for water and oil coolants. This includes the following:

- a) coolant temperature
 - air +0 °C to +40 °C
 - water +5 °C to +30 °C
 - oil –5 °C to +30 °C
- b) ambient temperature
 - +5 °C to +40 °C

- c) relative humidity
5 % to 85 % non-condensing
- d) dust and solid particle content
standard equipment is designed for clean air, refer to 2.5.1 of IEC 60664-1 pollution degree 2; any other condition constitutes "unusual service conditions" and requires specification by the customer; see IEC 60529 for degree of protection of enclosure;
- e) off-load periods shall be specified even if the ambient temperature is in the range defined above.

4.1.2.2 Mechanical installation conditions

The CDM/BDM shall be installed indoors on a rigid mounting surface, in areas or supplementary enclosure which do not seriously interfere with the ventilation or cooling system. An air-conditioner may be furnished to enhance the reliability of the CDM/BDM.

Other installation circumstances require special consideration and require specification and consultation with the manufacturer.

Vibration shall remain within the limits of IEC 60721-3-3, class 3M1 which is considered normal for stationary equipment.

Table 3 – Installation vibration limits

Frequency Hz	Amplitude mm	Acceleration m/s ²
$2 \leq f < 9$	0,3	n.a.
$9 \leq f < 200$	n.a.	1

Vibration beyond these limits, or use on non-stationary equipment, are considered unusual mechanical conditions.

4.1.3 Unusual environmental service conditions

The use of power converter equipment, associated drive control, and drive equipment under conditions departing from the usual conditions listed in IEC 60146-1-1 shall be considered unusual. These unusual service conditions shall be specified by the purchaser.

Unusual service conditions, of the kind listed below, may require special optional construction or protective features. The following conditions shall be communicated where known or specified:

- a) exposure to damaging fumes;
- b) exposure to excessive moisture (relative humidity greater than 85 %);
- 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 explosive mixtures of dust or gases;
- h) exposure to salt air;
- i) exposure to abnormal vibration, shock or tilting;
- j) exposure to weather or dripping water;
- k) exposure to unusual transportation or storage conditions;

- l) exposure to extreme or sudden changes in temperature;
- m) unusual space limitations;
- n) cooling water containing acid or impurities which cause excessive scale, sludge, electrolysis or corrosion;
- o) unusually high nuclear radiation;
- p) altitudes above 1 000 m (3 300 ft);
- q) long off-load periods;
- r) outdoor equipment.

4.1.4 Installation, commissioning and operation

Installation, commissioning, and operation have the same normal and unusual service conditions.

4.2 Storage of equipment

The equipment shall be placed under adequate cover immediately upon receipt if packing coverings are not generally suitable for outdoor or unprotected storage.

4.2.1 Climatic conditions

Equipment shall be capable of storage under environmental conditions as specified in IEC 60721-3-1. This includes the following:

- a) ambient temperature class: 1K4: –25 °C to +55 °C
- b) relative humidity class: 1K3: 5 % to 95 %

Modules and panels shall be protected from condensation. If any part of the equipment is not to be installed immediately, it shall be stored in a clean, dry place and protected from variations in temperature, high humidity, and dust. If possible, sudden changes in temperature and humidity should be avoided. If the temperature of the storage room varies to such an extent that the equipment surfaces are exposed to sweating or freezing conditions, the equipment shall be protected by a safe, reliable heating system which will keep the temperature of the equipment slightly above that of the storage room. If the equipment has been exposed to low temperature for an extended period of time it should not be unpacked until it has reached room temperature, otherwise it will sweat. The presence of moisture on certain internal parts can cause electrical failure.

4.2.2 Specific storage hazards

The following require particular attention:

- a) water – except for equipment specifically designed for outdoor installation, equipment shall be protected from rain, snow, sleet, etc.;
- b) altitude – equipment should not be stored above 3 000 m above sea level;
- c) corrosive materials – equipment shall 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);
- e) rodents and fungi – when storage conditions are likely to involve rodent or fungus attack, equipment specifications shall include protective items;
 - rodents – materials on the outside of the equipment and the size of apertures for cooling, connection, etc. shall be specified so as to discourage rodent attack or entry;
 - fungi – materials shall be specified for a degree of fungus resistance suitable for the storage and operating environments.

4.3 Transportation

4.3.1 Climatic conditions

Equipment shall be capable of transportation in the supplier's standard package, under environmental conditions as specified in class 2K3 of IEC 60721-3-2. This includes the following:

- a) ambient temperature: $-25\text{ }^{\circ}\text{C}$ to $+70\text{ }^{\circ}\text{C}$

NOTE – Temperature limits refer to the ambient temperature immediate surrounding the equipment (for example inside a container).

- b) relative humidity: 95 % at $+40\text{ }^{\circ}\text{C}$

NOTE – Some combinations of temperature and humidity may cause condensation.

4.3.2 Unusual climatic conditions

Where transportation temperatures below $-25\text{ }^{\circ}\text{C}$ are anticipated, the use of heated transport or the removal of selected low temperature sensitive components is required.

4.3.3 Mechanical conditions

Equipment shall be capable of transportation, in the supplier's standard package, within the limits prescribed in class 2M1 of IEC 60721-3-2.

This includes vibrations and shocks (see tables 4 and 5).

Table 4 – Transportation vibration limits

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

Table 5 – Transportation shock limits

Mass kg	Height of free fall m
$M < 20$	0,25
$20 \leq M < 100$	0,25
$100 \leq M$	0,10

NOTE 1 – If a shock and vibration environment beyond those limits is anticipated, special packaging or transport is required.

NOTE 2 – If a less damaging environment is known to exist, packaging may reflect reduced requirements by agreement between manufacturer/supplier, user, and carrier.

5 Ratings

5.1 BDM input ratings

5.1.1 Input voltages

The BDM input ratings shall be stated by the manufacturer. Preferred values are:

- a) 100, 110, 200, 220, 230*, 240, 380, 400*, 415, 440, 500, 660, 690* V at 50 Hz;
- b) 100, 115, 120, 200, 208, 220, 230, 240, 400, 440, 460, 480, 575, 600 V at 60 Hz.

5.1.2 Input currents

There are two input currents:

- converter alone: I_{VN} ;
this value shall be stated by the manufacturer at the minimum a.c. line impedance;
- CDM or BDM: I_{LN} ;
this value includes current required by auxiliaries I_{XN} .

5.2 BDM output ratings

5.2.1 Continuous output ratings

Continuous output ratings shall be stated by the manufacturer and shall be in terms of voltage (U_{dN}) and current (I_{dN}).

A rated output power can also be given as a general guide to assist the user in motor selection.

NOTE 1 – Rating in term of U_{dN} and I_{dN} allows use of direct measurement techniques and adequately addresses conductor current capacity.

NOTE 2 – When CDM and motor are not provided by the same manufacturer/supplier, information is to be exchanged to define proper performance and compatibility of CDM and motor.

5.2.2 Overload capability

PDS shall be rated for one of the following overload capabilities, unless otherwise specified. The overload capability applies to the rated speed range (see also note 3).

- a) Following continuous operation at rated output current, 150 % of rated output current (I_{dN}) for 45 s, followed by a period of load current less than rated current and of such duration that the r.m.s. output current over the duty cycle does not exceed rated output current (I_{dN}).

Example: if the duty cycle requires 150 % of rated current for 30 s in every 5 min, the remaining 4,5 min must be at approximately 92 % of rated current or less to maintain an r.m.s. value ≤ 100 %. If the requirement is 30 s out of 30 min, the remaining 29,5 min must be at approximately 98 % of rated current or less.

NOTE 1 – The overload is co-ordinated with occasional excess current of the motor; see 18.3 of IEC 60034-1:

- 45 s for machine output rating ≤ 1 kW per 1 r/min,
- 30 s for machine output rating > 1 kW per 1 r/min.

There is an alternative rating in common use: following continuous operation at rated output current, 150 % of rated output current (I_{dN}) for 1 min, followed by a period of load current less than rated current and of such duration that the r.m.s. output current over the duty cycle does not exceed rated output current (I_{dN}).

* Standard voltages as specified in IEC 60038.

Example: if the duty cycle requires 150 % of rated current for 1 min in every 10 min, the remaining 9 min must be at approximately 92 % of rated current or less to maintain an r.m.s. value ≤ 100 %. If the requirement is 1 min out of 60 min, the remaining 59 min must be at approximately 98 % of rated current or less.

- b) Following continuous operation at rated output current, 125 % of rated output current (I_{dN}) for 1 min, followed by a period of load current less than rated and of such duration that the r.m.s. output current over the duty cycle does not exceed rated output current (I_{dN}).

Example: if the duty cycle requires 125 % of rated current for 1 min in every 10 min, the remaining 9 min must be at approximately 96 % of rated current or less to maintain an r.m.s. value ≤ 100 %. If the requirement is 1 min out of 60 min, the remaining 59 min must be at approximately 99 % of rated current or less.

- c) Following continuous operation at rated output current, 110 % of rated output current (I_{dN}) for 1 min, followed by a period of load current less than rated and of such duration that the r.m.s. output current over the duty cycle does not exceed rated output current (I_{dN}).

Example: if the duty cycle requires 110 % of rated current for 1 min in every 10 min, the remaining 9 min must be at approximately 98 % of rated current or less to maintain an r.m.s. value ≤ 100 %. If the requirement is 1 min out of 60 min, the remaining 59 min must be at approximately 99 % of rated current or less.

NOTE 2 – The relationship between the overload currents specified and the torque developed by the motor is not covered by the above.

NOTE 3 – Special overload conditions can be specified between the user and the supplier/manufacture. For example, overload magnitude and duration may be the subject of such specification, examples of duty classes are given in table 3 of IEC 60146-1-1. See also 2.5.2 where it is noted that complex cases can be covered by IEC 61136-1.

5.2.3 Speed range

The speed shall be capable of being adjusted over a range of not less than eight to one by armature voltage control.

This speed range may be extended by motor field weakening to a maximum speed depending on the motor rating (see figure A.1).

NOTE – Operation below base speed:

drives are capable of operation at any speed within the rated speed range. When drives are operated continuously at rated torque at speeds below the rated base speed, the temperature rise of the motor may exceed the rated full load value.

To meet the specified duty cycle and torque requirements of the load for a given application, the drive system design should assure adequate torque capability at reduced speed with a safe motor temperature rise.

5.2.4 Existing d.c. voltage ratings

Inverting operation may require reduction of armature voltage.

A three-phase line commutated converter can fail in the inverting mode due to excessive d.c./a.c. ratio. This ratio can have its large value due to a low a.c. line or to a large motor terminal voltage.

The low a.c. line may be due to a large motor starting on the power system causing a line dip, or to a properly placed commutation notch from another converter.

The excessive motor terminal voltage can be due to a large motor counter EMF or a high rate of decreasing motor current (the armature current rate times the motor inductance results in an increased motor terminal voltage).

Usual d.c./a.c. ratio for typical industrial conditions is about 1,01 or 1,02 (this d.c./a.c. ratio is motor counter ($EMF + L_A dI/dt$) divided by a.c. nominal line voltage).

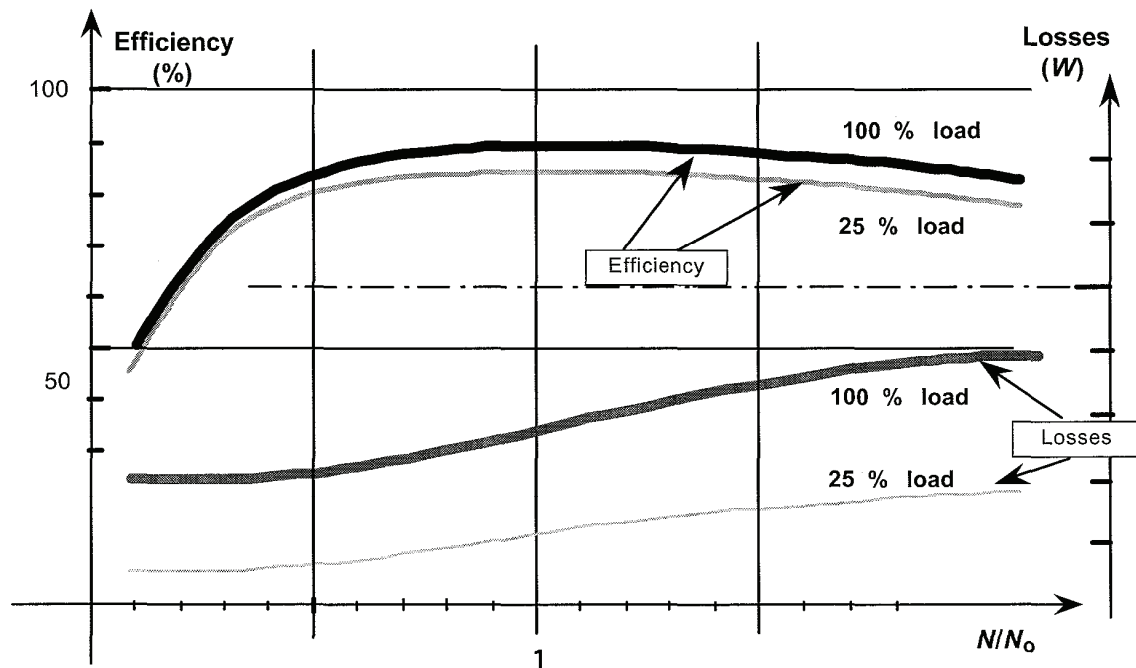
5.3 Efficiency and losses

The equipment included in the determination of the overall efficiency shall be stated.

The losses or efficiency of the PDS or of the CDM/BDM (see 2.5.8) shall be given by the manufacturer at rated load and base speed.

NOTE - The ventilation losses of the forced ventilated motor are included in the PDS losses, as those of a self ventilated motor, and in both cases they are not included in the CDM losses.

An example of variation of efficiency and losses versus speed is given in figure 5.



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Figure 5 – Typical curves for efficiency and losses of a PDS

5.4 Ripple

The ripple content of the converter is designated by the type of conversion, as indicated below (see figure F.1).

- | | |
|--------|---|
| Type A | Direct current generator <ul style="list-style-type: none"> – battery, – polyphase rectifier having no less than 12 pulses per cycle and maximum 15 % phase control, – any power supply that provides sufficient series inductance to obtain 6 % peak-to-peak, or less, armature current ripple. |
| Type B | Three-phase full wave power supply having 12 controlled pulses per cycle, without free-wheeling diode and without series inductance added in the motor armature circuit. |
| Type C | Three-phase full wave power supply having six controlled pulses per cycle, without free-wheeling diode and without series inductance added in the motor armature circuit. |