

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 kV

The European Standard EN 61800-4:2003 has the status of a
British Standard

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National foreword

This British Standard is the official English language version of EN 61800-4:2003. It is identical with IEC 61800-4:2002.

The UK participation in its preparation was entrusted to Technical Committee PEL/22, Power electronics, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
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**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 kV
(IEC 61800-4:2002)**

Entraînements électriques de puissance
à vitesse variable
Partie 4: Exigences générales -
Spécifications de dimensionnement
pour systèmes d'entraînements
de puissance en courant alternatif
de tension supérieure à 1 000 V alternatif
et ne dépassant pas 35 kV
(CEI 61800-4:2002)

Drehzahlveränderbare elektrische
Antriebe
Teil 4: Allgemeine Anforderungen -
Festlegungen für die Bemessung
von Wechselstrom-Antriebssystemen
über 1 000 V AC und höchstens 35 kV
(IEC 61800-4:2002)

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CENELEC

European Committee for Electrotechnical Standardization
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Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Foreword

The text of document 22G/99/FDIS, future edition 1 of IEC 61800-4, prepared by SC 22G, Semiconductor power converters for adjustable speed electric drive systems, of IEC TC 22, Power electronic systems and equipment, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61800-4 on 2002-11-01.

The following dates were fixed:

- latest date by which the EN has to be implemented
at national level by publication of an identical
national standard or by endorsement dop) 2003-08-01
- latest date by which the national standards conflicting
with the EN have to be withdrawn dow) 2005-11-01

Annexes designated "normative" are part of the body of the standard.
Annexes designated "informative" are given for information only.
In this standard, annex ZA normative and annexes A, B and C are informative.
Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61800-4:2002 was approved by CENELEC as a European Standard without any modification.

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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 kV

1 Scope

This part of IEC 61800 applies to adjustable speed a.c. drive systems that include power conversion, control equipment and a motor. Excluded are traction for railway applications and electrical vehicle drives.

It applies to power drive systems (see figure 1) with converter voltages (line-to-line voltage), between 1 kV a.c. and 35 kV a.c., input side 50 Hz or 60 Hz, and load side frequencies up to 600 Hz. Requirements for voltages above 15 kV are not included and are defined by agreement between the manufacturer and the system supplier.

For power drive systems, with voltages above 1 kV, using a step-down input transformer and/or a step-up output transformer in connection with a low voltage converter (below 1 000 V), IEC 61800-2 applies.

EMC aspects are covered in IEC 61800-3.

Specific safety requirements for drive systems with voltage above 1 kV will be covered in IEC 61800-5.

This standard gives the characteristics of the converters, their topologies and their relationship with the complete a.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, topologies and testing. Furthermore, it deals with application guidelines, such as control strategies, torsion analysis, recommendations for earthing and drive system component integration.

2 Normative references

The following referenced documents are indispensable for the application 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 60034-1, *Rotating electrical machines – Part 1: Rating and performance*

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)*
Amendment 1 (1995)
Amendment 2 (1996)

IEC 60034-2A:1974, *Rotating electrical machines – Part 2: Methods for determining losses and efficiency of rotating electrical machinery from tests (excluding machines for traction vehicles) – First supplement: Measurement of losses by the calorimetric method*

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

IEC 60034-6:1991, *Rotating electrical machines – Part 6: Methods of cooling (IC Code)*

IEC 60034-7, *Rotating electrical machines – Part 7: Classification of types of constructions and mounting arrangements (IM Code)*

IEC 60034-9:1997, *Rotating electrical machines – Part 9: Noise limits*

IEC 60034-14:1996, *Rotating electrical machines – Part 14: Mechanical vibration of certain machines with shaft heights 56 mm and higher – Measurement, evaluation and limits of vibration*

IEC 60034-17:1998, *Rotating electrical machines – Part 17: Cage induction motors when fed from converters – Application guide*

IEC 60034-18-31:1992, *Rotating electrical machines – Part 18: Functional evaluation of insulation systems – Section 31: Test procedures for form-wound windings – Thermal evaluation and classification of insulation systems used in machines up to and including 50 MVA and 15 kV*
Amendment 1 (1996)

IEC 60038:1983, *IEC standard voltages*
Amendment 1 (1994)
Amendment 2 (1997)

IEC 60050-111:1996, *International Electrotechnical Vocabulary (IEV) – Chapter 111: Physics and chemistry*

IEC 60050-151:2001, *International Electrotechnical Vocabulary (IEV) – Part 151: Electrical and magnetic devices*

IEC 60050-351:1998, *International Electrotechnical Vocabulary (IEV) – Part 351: Automatic control*

IEC 60050-441:1984, *International Electrotechnical Vocabulary (IEV) – Switchgear, controlgear and fuses*
Amendment 1 (2000)

IEC 60050-551:1998, *International Electrotechnical Vocabulary (IEV) – Part 551: Power electronics*

IEC 60050-601:1985, *International Electrotechnical Vocabulary (IEV) – Chapter 601: Generation, transmission and distribution of electricity – General*
Amendment 1 (1998)

IEC 60076-1:2000, *Power transformers – Part 1: General*

IEC 60076-2:1993, *Power transformers – Part 2: Temperature rise*

IEC 60076-3:2000, *Power transformers – Part 3: Insulation levels, dielectric tests and external clearances in air*

IEC 60076-5:2000, *Power transformers – Part 5: Ability to withstand short circuit*

IEC 60076-8:1997, *Power transformers – Part 8: Application guide*

IEC 60146-1-1:1991, *Semiconductor convertors – General requirements and line commutated convertors – Part 1-1: Specifications of basic requirements*
Amendment 1 (1996)

IEC 60146-1-2:1991, *Semiconductor convertors – General requirements and line commutated convertors – Part 1-2: Application guide*

IEC 60146-1-3:1991, *Semiconductor convertors – General requirements and line commutated convertors – Part 1-3: Transformers and reactors*

IEC 60146-2:1999, *Semiconductor convertors – Part 2: Self-commutated semi-conductor convertors including direct d.c. convertors*

IEC 60146-6:1992, *Semiconductor convertors – Part 6: Application guide for the protection of semiconductor convertors against overcurrent by fuses*

IEC 60204-11:2000, *Safety of machinery – Electrical equipment of machines – Part 11: Requirements for HV equipment for voltages above 1 000 V a.c. or 1 500 V d.c. and not exceeding 36 kV*

IEC 60417 (all parts): *Graphical symbols for use on equipment*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*
Amendment 1 (1999)

IEC 60664-1:2000, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

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*
Amendment 1 (1995)
Amendment 2 (1996)

IEC 60726:1982, *Dry type power transformers*
Amendment 1 (1986)

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*

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 61378-1:1997, *Converter transformers – Part 1: Transformers for industrial applications*

IEC 61800-2:1998, *Adjustable speed electrical power drive systems – Part 2: General requirements – Rating specifications for low voltage adjustable frequency a.c. power drive systems*

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

ISO 1680:1999, *Acoustics – Test code for the measurement of airborne noise emitted by rotating electrical machines*

3 Definitions

For the purposes of this part of IEC 61800, the following definitions, and the definitions given in IEC 60050(111), IEC 60050(151), IEC 60050(351), IEC 60050(441), IEC 60050(551), IEC 60050(601), IEC 60146-1-1, IEC 60146-1-2, and IEC 60146-1-3 apply.

3.1 System

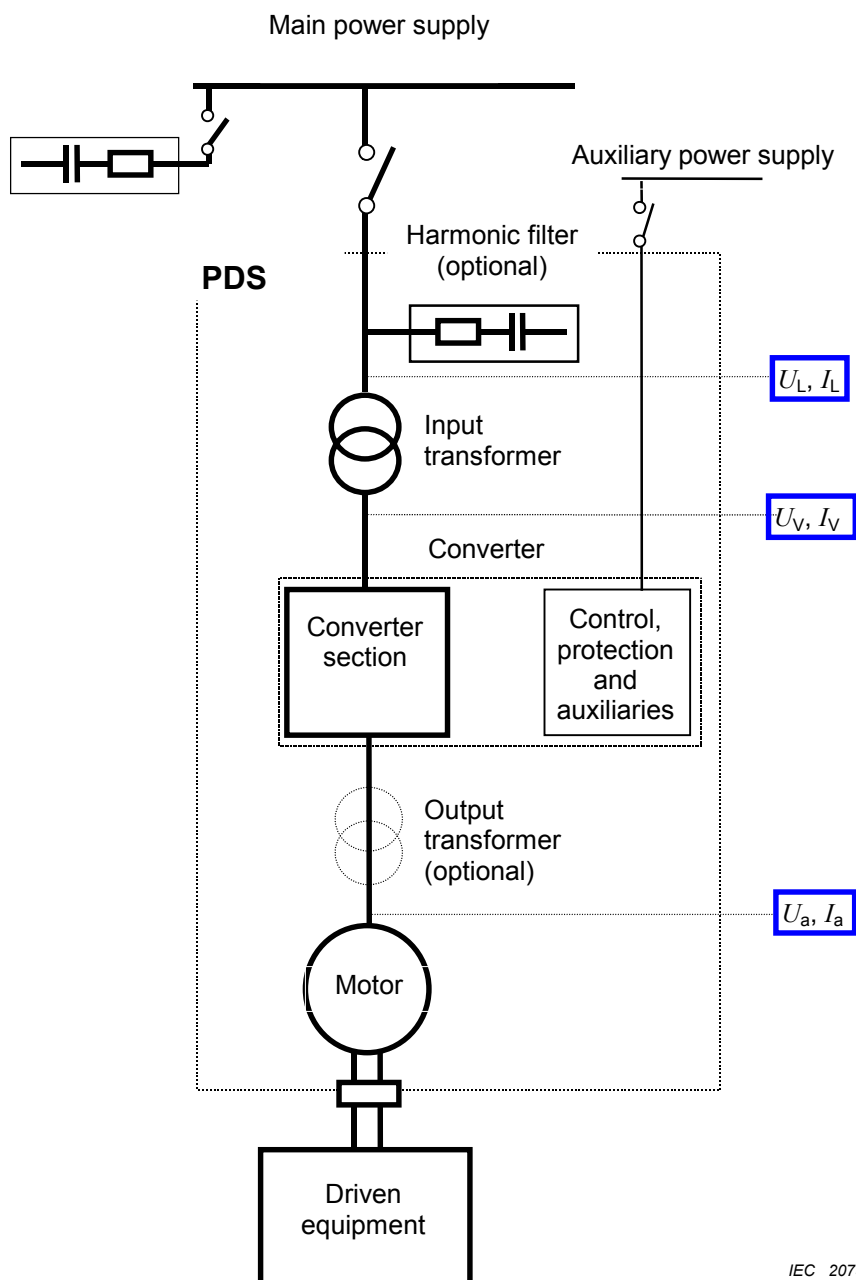
3.1.1

a.c. power drive system (PDS) with voltage above 1 kV (see figure 1)

system consisting of:

- power equipment (possible harmonic filters, input transformer, converter section, possible output transformer, a.c. motor);
- control, protection and auxiliaries

NOTE 1 Figure 1 illustrates the main functional elements. It also includes equipment which may be optional on many drive systems. It is intended to encompass a wide variety of a.c. drive configuration possibilities. The converter section does not illustrate or imply a specific topology using a specific type of switching device, due to the wide variety of combinations in current use. An input and/or output filter may be included in the converter section (except harmonic filters, which are listed separately). See clause 4 and annex A.



IEC 2075/02

Figure 1 – Functional diagram of an a.c. adjustable speed power drive system (PDS) – Voltage above 1 kV

NOTE 2 U_a represents the output voltage of the converter and U_A represents the voltage at the terminals of the motor. In the case where there is no output transformer and moderate cable lengths, $U_a = U_A$.

NOTE 3 Auxiliary supply may also be derived internally from the PDS, if it is considered sufficiently reliable.

3.1.2

point of coupling

PCC, IPC, PC: these definitions are given in IEC 61000-2-4:

- PCC is the point of common coupling on a public network;
- IPC is the in-plant point of coupling on a private network;
- PC is the point of coupling for either of these cases

3.1.3**harmonic filter**

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

3.1.4**regeneration**

process of converting the mechanical energy of the system to electrical energy and transferring it to the input supply

NOTE During regeneration the motor is working as a generator and the ratings of the motor may be different.

3.1.5**PDS efficiency, η_D**

the 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 feeding lines (see figure 1 and figure 25), and is usually expressed as a percentage

NOTE Auxiliaries and any needed excitation power are included in the power drawn from the input.

3.1.6**power conversion efficiency, η_C**

the efficiency, η_C , of the power conversion is the ratio of the power delivered by the converter to the total power drawn from the input power supplies feeding lines, including the converter auxiliaries (see figure 1 and figure 25), and is usually expressed as a percentage

3.1.7**fundamental frequency**

a frequency, in the spectrum obtained from a Fourier transform of a time function, to which all the frequencies of the spectrum are referred. For the purpose of IEC 61800, the fundamental frequency is the same as the power frequency supplying the converter, or supplied by the converter according to the case which is considered

[IEV 101-14-50 modified]

NOTE 1 In the case of a periodic function, the fundamental frequency is generally equal to the frequency of the function itself (see IEV 551-20-03 and IEV 551-20-01). The above definition corresponds to the genuine definition of "reference fundamental frequency" according to IEV 551-20-04 and IEV 551-20-02, for which the term "reference" may be omitted where there is no risk of ambiguity. This definition has been adopted for the revision of IEC 61000-2-2 and IEC 61000-2-4.

NOTE 2 In case of any remaining risk of ambiguity, the power supply frequency should be referred to the polarity and speed of rotation of the synchronous generator(s) feeding the system.

NOTE 3 This definition may be applied to any industrial power supply network, without regard to the load it supplies (a single load or a combination of loads, rotating machines or other load), and even if the generator feeding the network is a static converter.

3.1.8**fundamental component (or fundamental)**

the component whose frequency is the fundamental frequency

3.1.9**harmonic frequency (order h)**

a frequency which is an integer multiple of the fundamental frequency, the ratio of the harmonic frequency to the fundamental frequency is named harmonic order (recommended notation " h ") (see IEV 551-20-05, IEV 551-20-07 and IEV 551-20-09)

3.1.10**harmonic component**

any of the components having a harmonic frequency, its value is normally expressed as a r.m.s. value

NOTE For brevity, such a component may be referred to simply as a harmonic.

3.1.11

interharmonic frequency

any frequency which is not an integer multiple of the fundamental frequency (see IEC 551-20-05, IEC 551-20-07 and IEC 551-20-09)

NOTE 1 By extension of the harmonic order, the interharmonic order is the ratio of interharmonic frequency to the fundamental frequency, this ratio is not an integer (recommended notation "*m*").

NOTE 2 In the case where "*m* < 1" the term of sub-harmonic frequency may also be used (see IEC 551-20-10).

3.1.12

interharmonic component

a component having an interharmonic frequency, its value is normally expressed as an r.m.s. value

NOTE 1 For brevity, such a component may be referred to simply as an interharmonic

NOTE 2 For the purpose of IEC 61800, and as stated in IEC 61000-4-7, the time window has a width of 10 fundamental periods (50 Hz systems) or 12 fundamental periods (60 Hz systems), i.e. approximately 200 ms. The difference in frequency between two consecutive interharmonic components is, therefore, approximately 5 Hz. In case of other fundamental frequencies, the time window should be selected between 6 fundamental periods (approximately 1 000 ms at 6 Hz) and 18 fundamental periods (approximately 100 ms at 180 Hz).

3.1.13

harmonic content, *HC*

sum of the harmonic components of a periodic quantity

[IEV 551-20-12]

NOTE 1 The harmonic content is a time function.

NOTE 2 For practical analysis, an approximation of the periodicity may be necessary.

NOTE 3 The harmonic content depends on the choice of the fundamental component. If it is not clear from the context which one is used an indication should be given.

NOTE 4 In practice, the sum is limited to the order *H*.

NOTE 5 The r.m.s. value of the harmonic content is:

$$HC = \sqrt{\sum_{h=2}^{h=H} Q_h^2}$$

where

h is the harmonic order (according to 3.1.9);

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

H is 40 for the purposes of this standard.

3.1.14

total harmonic distortion, *THD*

ratio of the r.m.s. value of the harmonic content to the r.m.s. value of the fundamental component or the reference fundamental component of an alternating quantity

[IEV 551-20-13]

$$THD = \frac{HC}{Q_1} = \sqrt{\sum_{h=2}^{h=H} \left(\frac{Q_h}{Q_1} \right)^2}$$

where

Q represents either current or voltage

Q₁ is the r.m.s. value of the fundamental component;

h is the harmonic order (according to 3.1.9);

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

H is 40 for the purposes of this standard.

3.1.15**total distortion content, DC**

quantity obtained by subtracting from an alternating quantity its fundamental component or its reference fundamental component

[IEV 551-20-11]

NOTE 1 The total distortion content includes harmonic components and interharmonic components if any.

NOTE 2 The total distortion content depends on the choice of the fundamental component. If it is not clear from the context which one is subtracted an indication should be given.

NOTE 3 The total distortion content is a time function.

NOTE 4 An alternating quantity is a periodic quantity with zero DC component.

NOTE 5 The r.m.s. value of the total distortion content is

$$DC = \sqrt{Q^2 - Q_1^2}$$

where in addition to notations in 3.1.14:

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

see also IEV 101-14-54.

3.1.16**total distortion ratio, TDR**

ratio of the r.m.s. value of the total distortion content to the r.m.s value of the fundamental component or the reference fundamental component of an alternating quantity

[IEV 551-20-14]

$$TDR = \frac{DC}{Q_1} = \frac{\sqrt{Q^2 - Q_1^2}}{Q_1}$$

NOTE 1 The total distortion ratio depends on the choice of the fundamental component. If it is not clear from the context which one is used an indication should be given.

NOTE 2 The total distortion ratio may be approximated to a certain harmonic order. This is to be stated.

NOTE 3 THD may be considered as an approximation of TDR where interharmonics are disregarded due to their low amplitude.

NOTE 4 The waveform of the voltage on the distribution network is usually less distorted than the waveform of the current. Therefore, the assessment of these two ratios related to voltage, total harmonic distortion THD and total distortion ratio TDR , leads to the same result. There may be a significant difference when applied to current.

3.1.17**total distortion factor, TDF**

ratio of the r.m.s. value of the total distortion content to the r.m.s. value of an alternating quantity

[IEV 551-20-16 and IEV 101-14-55]

$$TDF = \frac{DC}{Q} = \frac{\sqrt{Q^2 - Q_1^2}}{Q}$$

NOTE 1 The total distortion ratio depends on the choice of the fundamental component. If it is not clear from the context which one is used an indication should be given.

NOTE 2 The ratio between TDF and TDR equals the ratio between the r.m.s. value of the fundamental component and the total r.m.s. value. It is the fundamental factor [IEV 551-20-17 and IEV 161-02-22]:

$$FF = \frac{Q_1}{Q} = \frac{TDF}{TDR} \leq 1$$

3.1.18**individual harmonic distortion, IDR**

ratio of any component to the fundamental

3.1.19

characteristic current harmonics

orders of the current harmonics produced by converter equipment in the course of normal operation

NOTE 1 For example, in a six-pulse converter the characteristic current harmonics are the non triple, odd harmonics, $h = 6k \pm 1$ (k any integer).

NOTE 2 In addition to power system frequency harmonics, there can be other harmonics resulting from interaction with the converter load. They are called interharmonics.

3.1.20

rated voltage

the r.m.s. line-to-line voltage under rated conditions

Primary side of input transformer: U_{LN}

Converter input: U_{VN}

Converter output: U_{aN}

Motor voltage: U_{AN}

3.1.21

rated fundamental voltage

the r.m.s. value of the fundamental voltage under rated conditions

Primary side of input transformer: U_{LN1}

Converter input: U_{VN1}

Converter output: U_{aN1}

Motor fundamental voltage: U_{AN1}

3.1.22

rated a.c. current

the r.m.s. value of the a.c. current under rated conditions

Primary side of input transformer: I_{LN}

Converter input: I_{VN}

Converter output: I_{aN}

Rated motor current: I_{AN}

3.1.23

rated fundamental current

the r.m.s. value of the fundamental component of the current under rated conditions

Primary side of input transformer: I_{LN1}

Converter input: I_{VN1}

Converter output: I_{aN1}

Rated fundamental motor current: I_{AN1}

3.1.24

overload capability

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

Primary side of input transformer: I_{LM}

Converter input: I_{VM}

Converter output: I_{aM}

Motor overload current: I_{AM}

3.2 PDS input parameters

3.2.1

line-side input power, P_L

the total active power at the line input

3.2.2

line-side input apparent power, S_L

the total apparent power at the line input

3.2.3

input total power factor, λ_L

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

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

$$\lambda_L = \frac{U_L \times I_{L1} \sqrt{3} \times \cos \varphi_{L1}}{U_L \times I_L \times \sqrt{3}} = \frac{I_{L1}}{I_L} \times \cos \varphi_{L1}$$

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

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

3.2.4

voltage unbalance (imbalance)

in a polyphase system, a condition in which the r.m.s. values of the fundamental component of the line voltages, or the phase angle between consecutive phases, are not all equal

NOTE 1 The degree of that inequality is usually expressed as the ratios of the negative and zero sequence components to the positive sequence component [IEV 161-08-09, modified]

U_{12} , U_{23} and U_{31} are the three line-to-line voltages, with $\delta_{ij} = (U_{ij} - U_{average}) / (3 \times U_{average})$ the deviation for each of the three line-to-line voltages, and τ the voltage unbalance as the ratio of the negative sequence voltage amplitude to the positive sequence voltage amplitude,

$$\tau = \sqrt{6 \times \sum_{ij=1}^3 \delta_{ij}^2}$$

NOTE 2 The above formula in note 1 gives an excellent approximation (with an error of less than 5 % for a band of ± 20 % in amplitudes and $\pm 15^\circ$ in phase shift from the corresponding ideal line to neutral balance system – positive sequence or negative sequence). The much more simple approximation:

$$\tau = (2/3) \times [(U_{max} - U_{min}) / U_{average}]$$

provides acceptable results for τ up to 7 % (absolute error less than 1 %). Another simple approximation gives results with a comparable error:

$$\tau = \text{MAX} [(U_{ij} - U_{average}) / U_{average}].$$

3.2.5

supply transient overvoltage

peak instantaneous voltage that may appear between the input lines to the PDS, with the PDS disconnected

3.2.6

supply transient energy

the energy which the supply system, due to a transient, is capable of delivering at the PDS terminals

3.3 Converter

3.3.1

converter section (voltage above 1 kV)

electronic power converter unit operating at voltage above 1 kV and not exceeding 35 kV according to figure 1

3.3.2

converter input filter

circuits connected to the power input of the converter to reduce $d\nu/dt$ (voltage stress of transformer insulation) or radio frequency emissions

3.3.3

converter d.c. link voltage, U_d

average value of the voltage in the d.c. link (on the input converter side)

3.3.4

converter d.c. link current, I_d

average value of the current in the d.c. link (on the input converter side)

3.3.5

snubber (circuit)

a sub-circuit connected to one or more power semiconductor devices in order to relieve it (them) of stress in regard of high rate of rise of current or voltage, overvoltage transients, switching losses, etc.

3.3.6

d.c. link

power d.c. circuit linking the input converter and the output converter of an indirect converter, consisting of capacitors and/or reactors to reduce d.c. voltage or d.c. current ripple

3.3.7

converter output filter

circuits connected to the power output of the converter to reduce $d\nu/dt$ (voltage stress of motor insulation and generating bearing currents) or harmonics (losses)

3.3.8

a.c. converter output power, P_{a1}

the fundamental power at the converter output terminals

3.3.9

apparent converter output power, S_a

the total apparent power at the converter output terminals

3.3.10

dynamic short-circuit output current

the transient d.c. or a.c. current which flows from the converter into a short-circuit across the output terminals

3.3.11

operating frequency range

range of fundamental frequencies over which the converter output is controlled ($f_{\min}$, $f_{\max}$), under specified load conditions

3.4 PDS output parameters

3.4.1

load envelope

area in torque versus speed in which the PDS is intended to operate under continuous load conditions

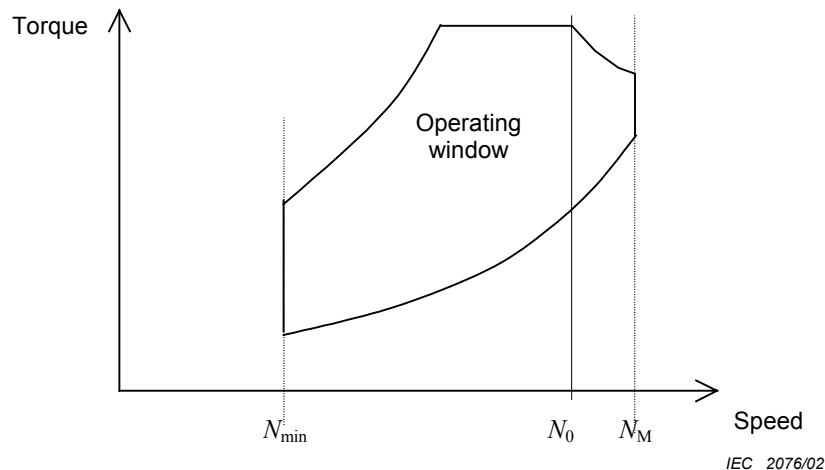


Figure 2 – Example of load envelope

3.4.2

minimum operating speed, $N_{\min}$

minimum motor operating speed required by driven equipment

3.4.3

maximum operating speed, N_M

maximum motor operating speed required by driven equipment

3.4.4

base speed, N_0

highest motor speed at which the PDS is capable to deliver continuously the rated torque

NOTE Base speed is the transition point between constant torque and field weakening operation.

3.4.5

field weakening operation

operation with reduced flux in a speed range between base speed (N_0) and maximum speed (N_M)

3.4.6

air-gap torque pulsation

cyclic fluctuation of motor air-gap torque at under steady-state conditions, defined as peak-to-peak value

3.5 Control

3.5.1

control system

electronic system which provides actuation of the power converter and status information as a result of various commands and feedbacks

3.5.2

controlled variable

system variable, in open-loop or closed-loop control of PDS

NOTE Some examples of controlled variables are voltage, stator current, frequency, speed, slip and torque

3.5.3

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

3.5.4

operating variable

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

3.5.5

open-loop control

control which does not use the measurement of the controlled variable

3.5.6

feedback control/closed-loop control

control in which the control action is dependent on the measurement of the controlled variable

3.5.7

stimulus

any excitation of a system which causes a reaction in response

NOTE Examples are given in 7.2.2.

3.5.8

disturbance

undesired and most frequently unpredictable change in an input variable, other than the reference variable

3.5.9

time response

the variation in time of an output variable of a system, produced by a specified variation of one of the input variables

3.5.10

step response

the time response of a system produced by a step-wise variation of one of the input variables

NOTE When the variation of the input variable is equal to one unit, the step response is called the unit step response.

3.6 Tests

3.6.1

type test

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

[IEV 151-16-16 modified]

3.6.2

routine test

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

[IEV 151-16-17 modified]

3.6.3

sampling test

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

[IEV 151-16-20 modified]

3.6.4

special test

test additional to type and routine tests, made either at the discretion of the system supplier or according to an agreement between the system supplier and customer or his representative

[IEC 61800-2, 7.1.4 modified]

3.6.5

acceptance test

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

[IEV 151-16-23]

3.6.6

commissioning test

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

[IEV 151-16-24, modified]

3.6.7

witness test

any of the above tests performed in the presence of the customer, the user or his representative (IEC 61800-2, 7.1.8)

3.6.8

separate component test

test on each individual main component which constitutes a PDS (transformer, motor, etc.)

3.6.9

drive system test

test on total PDS to ascertain total performance of the system

3.7 Symbols

Table 1 summarizes symbols which are the most commonly used.

Table 1 – Symbols

Symbol	Unit	Definition	Parameter
I_{aM}	A	3.1.24	Overload current (overload capability)
I_{aN}	A	3.1.22	Rated continuous output current
I_{aN1}	A	3.1.21	Rated fundamental output current
I_d	A	3.3.4	d.c. link current
I_{LN}	A	3.1.22	Line-side a.c. rated current of the PDS
I_{LN1}	A	3.1.23	Line-side fundamental a.c. rated current of the power converter
I_{VN}	A	3.1.22	Rated input current of the power converter
J	kgm ² or Nms ²		Moment of inertia
M_d	Nm		Air gap torque (electromagnetic torque)
M_s	Nm		Shaft torque
N	r/min		Motor speed
N_0	r/min	3.4.4	Base speed
N_M	r/min	3.4.3	Maximum operating speed
N_{min}	r/min	3.4.2	Minimum operating speed
P_{aN1}	W		Rated converter a.c. output power
P_{LN}	W	3.2.1	Rated input power
P_S	W		Output power (on the shaft of the motor)
R_{SI}		IEC 61800-3 B.2.1.3.6	Short-circuit current ratio $R_{SI}=(S_{SC} \text{ at a given point})/S_N$ equipment
S_{aN}	VA		Rated converter apparent output power
S_{LN}	VA	3.2.2	Rated input apparent power
TDR_a	%	See 3.1.16	Converter output total distortion ratio
TDR_L	%	See 3.1.16	Line-side total distortion ratio (with interharmonics)
THD_a	%	See 3.1.14	Converter output total harmonic distortion
THD_L	%	See 3.1.14	Line-side total harmonic distortion (without interharmonics)
U_{aN}/f_{aN}	V/Hz		Rated voltage to rated frequency ratio
U_{aN1}	V	3.1.21	Load side fundamental a.c. rated voltage
U_{LN}	V	3.1.20	Rated system voltage
U_{VN}	V	3.1.20	Converter input rated a.c. voltage
U_{VN1}	V	3.1.21	Converter input rated a.c. fundamental voltage
$\cos \varphi_{L1}$		IEC 61800-2	Line-side displacement factor
$\cos \varphi_{V1}$		IEC 61800-2	Converter input displacement factor
f_{LN}	Hz		Rated line frequency
η_C	%	3.1.6	Efficiency of power conversion
η_D	%	3.1.5	Efficiency of PDS
η_M	%	11.1	Efficiency of the motor
η_T	%	11.1	Efficiency of the transformer
λ_L		3.2.3	Input total power factor

NOTE 1 The index "L" is used for the line side (primary side of transformer) parameters or variables.

NOTE 2 The index "V" is used for the converter input side parameters or variables.

NOTE 3 The index "d" is used for the d.c. link parameters or variables.

NOTE 4 The index "a" is used for the converter output side parameters or variables.

NOTE 5 The index "A" is used for the motor side parameters or variables.

NOTE 6 The second index "N" is used for rated condition.

NOTE 7 The third index "1" is used for the fundamental component of a variable (order 1), etc.

4 Overview of drive system topologies

4.1 Topologies classification

The various drive systems topologies may be classified according to the following main criteria:

- converter configuration;
- commutation mode;
- motor type.

Any combination of the situations below can be used to form a drive system topology. Examples of commonly used drive system topologies are shown in annex A.

The classification of converters is between drive systems with *indirect converters* or *direct converters*. The second criterion for classification is with the commutation mode which may be external commutation or self-commutation.

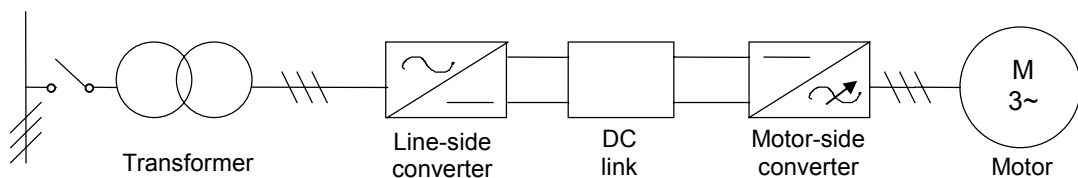
4.2 Converter configuration

4.2.1 Indirect converter

The power conversion from a fixed frequency and voltage a.c input to a variable frequency and voltage a.c. output is performed with an intermediate d.c. link, as in figure 3.

The d.c. link includes one or more filtering devices (series reactor, parallel capacitor or both).

In the case of an inductive d.c. link, the motor-side converter is named current source inverter (CSI). In the case of a capacitive d.c. link it is named voltage source inverter (VSI).



IEC 2077/02

Figure 3 – General structure of a drive system with an indirect converter

4.2.2 Direct converter

The power conversion from a fixed frequency and voltage a.c. input to a variable frequency and voltage a.c. output is performed without an intermediate d.c. link, as in figure 4.

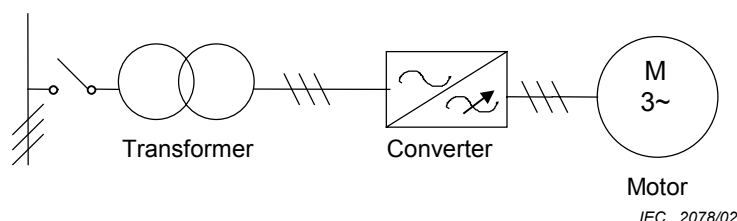


Figure 4 – General structure of a drive system with direct converter

The transformer in both figures usually presents one line-side three-phase winding and one or more secondary three-phase windings, depending on the nature of the connected converter. The latter may consist of multiple six-pulse converter modules, connected in series and/or parallel and sometimes with a sequential control, with the scope to improve the harmonic content and the power factor respectively.

4.2.3 Commutation mode

4.2.3.1 External commutation

External commutation means that commutation is due to a source outside the converter. This kind of commutation includes line commutation and load commutation. In case of indirect converters with a load commutated motor-side converter, this is named load commutated inverter (LCI).

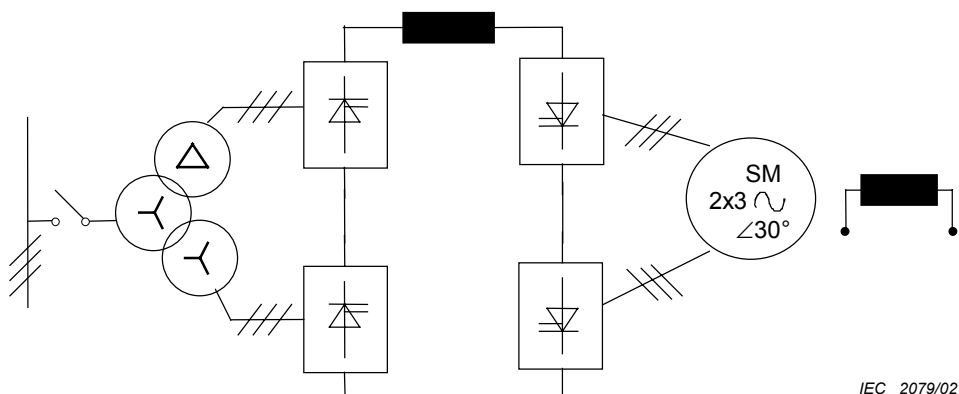
4.2.3.2 Self- commutation

Self-commutation means that commutation is performed by means of components within the converter.

4.3 Motor type

The main motor types include polyphase *synchronous motors* and *induction motors*. The most common configurations of both types are three-phase or multiple three-phase stator winding systems. Induction motors may be subdivided into cage induction motors and wound rotor induction motors.

Figure 5 shows an example of a configuration with multiple line-side and motor-side converter modules and with a motor with two separate stator winding systems.



IEC 2079/02

Figure 5 – Example of multiple converter modules and separate stator winding systems motor

4.4 By-pass and redundant configurations

Drive systems may have by-pass and/or redundant configurations to satisfy different aims, among which are the following:

- normal changing from a variable frequency supply to a mains frequency supply at the end of the system starting procedure;
- emergency switching from a variable frequency supply to a mains frequency 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.

NOTE In the case of bypass topology, care should be taken regarding the motor rating for the starting conditions without the converter.

Figure 6 shows an example of a bypass configuration for a drive system with indirect conversion: the bypass channel may include a transformer for voltage level matching.

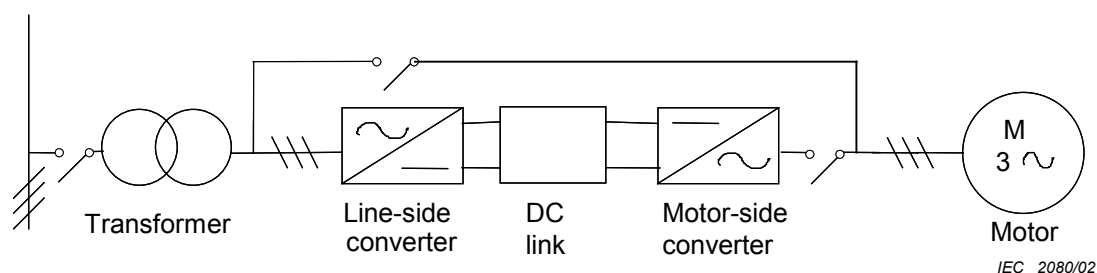


Figure 6 – Bypass configuration for system with indirect converter

An example of a redundant configuration is given in figure 7.

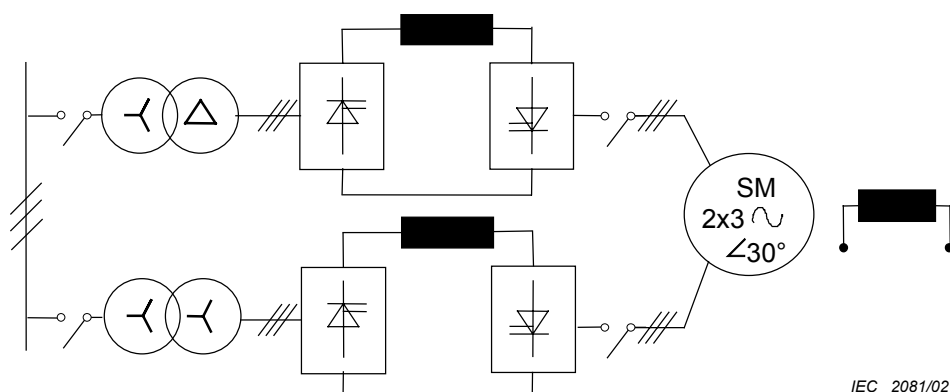


Figure 7 – LCI-synchronous motor in a partly redundant configuration

4.5 Regenerative and dynamic braking

4.5.1 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.

Power flow from the line to the motor is called “motoring operation”, while power flow from the motor to the line is called “regenerating operation”.

Many of the topologies illustrated in annex A are capable of four quadrant operation and therefore, regenerative braking.

4.5.2 Dynamic braking

In case of dynamic braking, energy is dissipated in a resistor.

As an example, figure 8 shows a VSI-inverter drive with a resistor in parallel to the d.c. link capacitor; when current reversal occurs, the chopper operates in such a way as to control the capacitor voltage, allowing the braking energy to be dissipated in the resistor.

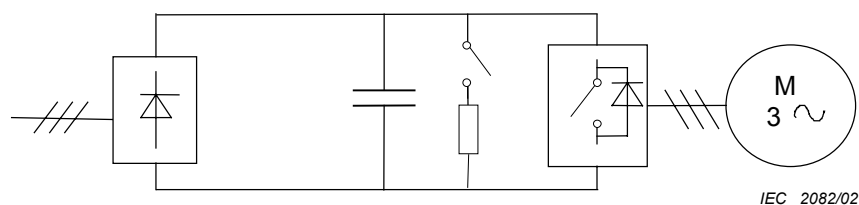


Figure 8 – Example of dynamic braking

5 Service conditions

5.1 Installation and operation

5.1.1 Electrical service conditions

5.1.1.1 Normal service conditions

Unless otherwise specified, the PDS shall be designed to operate under the electrical service conditions specified in table 2 below. The corresponding EMC acceptance criteria in the same structure can be found in 5.2 of IEC 61800-3.

**Table 2 – Service conditions for the voltage supply at the PDS terminals
(main and auxiliary)**

Phenomenon	Level	Reference document
Frequency variations	$f_{LN} \pm 2 \%$ $f_{LN} \pm 4 \%$ (for separated supply networks)	IEC 61800-3
Frequency rate of change	$\leq 2 \%$ f_{LN}/s	IEC 61800-3
Voltage variations	$\pm 10 \%$ $+10 \%$, -15% ≤ 1 min (see note 1)	IEC 61800-3
Voltage fluctuations	maximum step amplitude: – 12 % within the tolerance band – minimum interval between steps: 2 s – rise time: ≥ 5 periods of the supply	IEC 61800-3
Voltage dips	10 – 50 % $t \leq 100$ ms 10 – 100 % $t \leq 5$ s (see note 2)	IEC 61800-3
Voltage unbalance	main supply: 2 % (zero sequence and negative sequence components) auxiliary supply: 3 % (zero sequence and negative sequence components)	IEC 61800-3
Voltage harmonics: steady state transient	$THD \leq 10 \%$ steady state $THD \leq 15 \%$ $t \leq 15$ s (see note 3)	IEC 61800-3
Voltage interharmonics: steady state transient	$IDR \leq 0,5 \%$ $IDR \leq 0,75 \%$ $t \leq 15$ s	IEC 61000-2-4 Annex A
Commutation notches	depth: 40 % U_{LWM} main supply, area: 125 % $\times$ degrees auxiliary supply, area: 250 % $\times$ degrees	IEC 61800-3
NOTE 1 Rated operation at voltages below 100 % of rated voltage shall be subject to agreement between the customer and the system supplier. NOTE 2 In reference to performance criteria, as defined in table 1 of IEC 61800-3, for the main power port, the smaller dips of this table are associated with performance criterion B or C and the largest with criterion C. For the auxiliary power ports, the smaller dips are associated with performance criterion A or B and the largest with criterion B. NOTE 3 These figures represent the service conditions when the PDS is in operation.		

5.1.1.2 Source impedance

Protective devices of the PDS, particularly the line feeder protection (see 9.3), shall be designed to operate properly within a range of specified short-circuit current ratios (R_{SI}).

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

The maximum R_{SI} ratio for a standard design PDS to meet protection conditions shall be 100, determined at the point of coupling (PC).

In the case of a custom design, the actual range of R_{SI} shall be specified if less than 20 or higher than 100.

5.1.1.3 Repetitive and non-repetitive transients

A typical a.c. voltage waveform contains repetitive and non-repetitive transients. The transients are caused by converter commutation, switching of switchgears on the network, and disturbances on the power system.

The PDS shall be designed to operate in an environment with non-repetitive transients caused by switching the transformer of the PDS (see 9.2.1) or other transformer supplying the point of coupling (PC).

NOTE If unusually high overvoltages may occur at the PC, this should be specified by the customer. For example, a customer specification for a 6 kV supply states:

- in the case of remote switching: 15 kV voltage surge, 250/2 500 μ s;
- in the case of nearby switching: 12,3 kV voltage surge, 50/400 μ s.

5.1.1.4 Unusual electrical service conditions

The unusual service conditions shall be subject to a special agreement between the customer and the system supplier.

5.1.2 Environmental service conditions

5.1.2.1 Climatic conditions

The PDS (with the possible exceptions of the power transformer and motor when installed at different locations) shall operate under the environmental conditions specified in IEC 60721-3-3 for class 3K3, and section 2 of IEC 60146-1-1 for the cooling medium. This includes the following:

- a) temperature range of the cooling medium

air	0 °C to +40 °C
inlet water	+5 °C to +30 °C
- b) ambient temperature range

+5 °C to +40 °C	
+30 °C	daily average, air
+25 °C	yearly average, air;

- c) relative humidity
5 % to 85 % without condensation;
- d) altitude
1 000 m maximum above sea level;
- e) dust and solid particle content
equipment of standard design is designed for clean air, pollution degree 2, any other condition constitutes “unusual service conditions” and requires specification by the customer (see IEC 60529 for degrees of protection for enclosures);
- f) extended shut down periods
the customer should indicate, if such periods are foreseen, even if the ambient conditions are in the range defined above.

5.1.2.2 Mechanical installation conditions

The PDS, (with the possible exceptions of the power transformer and motor, when installed at different locations) shall be installed indoors on a rigid mounting surface or in a supplementary enclosure, which do not seriously interfere with the ventilation or cooling system. An air-conditioner may be furnished to enhance the reliability.

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

Vibration shall remain within the limits of IEC 60721-3-3, class 3M1, which is considered normal for stationary equipment. Vibration beyond these limits or use on non-stationary equipment are considered unusual mechanical conditions.

Table 3 – Installation vibration limits

Frequency Hz	Amplitude mm	Acceleration m/s ²
$2 \leq f < 9$	0,3	not applicable
$9 \leq f < 200$	not applicable	1

The main transformer (if any) and the motor shall comply with their applicable product standards (IEC 60076 or IEC 60726 and IEC 60034, respectively).

5.1.2.3 Unusual environmental service conditions

The use of power converter equipment, associated drive control, and drive equipment under conditions different from the usual conditions listed in IEC 60146-1-1 shall be considered unusual. The customer shall specify these unusual service conditions.

Operating conditions not specified as usual environmental conditions in 5.1.2 should be coordinated between the customer and the supplier of the equipment.

Identified unusual service conditions for the converter are the following:

- a) exposure to damaging fumes;
- b) exposure to excessive moisture (relative humidity greater than 85 %) and relative humidity changes (exceeding 0,005 p.u./h);

- c) exposure to excessive dust;
- d) exposure to abrasive dust;
- e) exposure to steam or water condensation;
- f) exposure to steam or oil vapor;
- 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 (exceeding 5 K/h);
- m) cooling water containing acid or impurities which cause excessive scale, sludge, electrolysis or corrosion or obstruction, sea and hard water;
- n) unusually high nuclear radiation;
- o) altitude above 1 000 m;
- p) outdoor equipment.

For unusual service conditions of the main transformer (if any) and motor, refer to the applicable product standards (IEC 60076 or IEC 60726 and IEC 60034, respectively).

5.1.3 Commissioning

Unless otherwise agreed upon, commissioning has the same normal and unusual service conditions as operation.

5.2 Transportation

5.2.1 Climatic conditions

5.2.1.1 General

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

5.2.1.2 Ambient temperature

–25 °C to +55 °C

–25 °C to +70 °C up to 24 h.

NOTE 1 Temperature limits refer to the ambient temperature immediately surrounding the equipment (for example, inside a container).

NOTE 2 These limits apply with cooling liquid removed.

NOTE 3 Lower limits for the highest temperature are possible, provided a warning is given.

5.2.1.3 Relative humidity

Less than 95 % at +40 °C

NOTE Some combinations of temperature and humidity may cause condensation.

5.2.1.4 Atmospheric pressure

Range 86 kPa to 106 kPa

The main transformer (if any) and the motor shall comply with their applicable product standards. (IEC 60076 or IEC 60726 and IEC 60034, respectively).

5.2.1.5 Unusual climatic conditions

Temperatures below -25°C .

Where transportation temperatures below -25°C are anticipated, the use of heated transport or the removal of selected low temperature sensitive components is required.

5.2.2 Mechanical conditions

5.2.2.1 General

Equipment shall be capable of transportation, in the supplier's package, within the limits prescribed in class 2M1 of IEC 60721-3-2. This includes the following requirements as far as vibration and shock are concerned.

5.2.2.2 Vibration limits

Limits are given in table 4.

Table 4 – Transportation vibration limits (see class 2M1 IEC 60721-3-2)

Frequency Hz	Amplitude mm	Acceleration m/s^2
$2 \leq f < 9$	3,5	Not applicable
$9 \leq f < 200$	Not applicable	10
$200 \leq f < 500$	Not applicable	15

5.2.2.3 Shock limits

The limits are those corresponding to a free fall height of 0,1 m.

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

NOTE 2 If a less damaging environment is known to exist, packaging may reflect reduced requirements by agreement between component manufacturers/system supplier, customer and carrier.

NOTE 3 The main transformer (if any) and the motor shall comply with their applicable product standards. (IEC 60076 or IEC 60726 and IEC 60034, respectively).

5.3 Storage of equipment

5.3.1 General

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

5.3.2 Climatic conditions

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

- a) Ambient temperature class 1K4:
–25 °C to +55 °C
- b) Relative humidity class 1K3:
5 % to 95 %
- c) Atmospheric pressure:
86 kPa to 106 kPa

These limits apply with cooling liquid removed.

Storage conditions and duration shall be defined and agreed upon between customer and system supplier.

For the converter, the transformer and the motor, the applicable product standards (IEC 60146, IEC 60076 or IEC 60726 and IEC 60034, respectively) take precedence.

5.3.3 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) **condensation** – sudden changes in temperature and humidity should be avoided;
- 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 of IEC 60721-3-1);
- 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 such 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.

6 Ratings

6.1 Power drive system (PDS)

6.1.1 General

The main power components specifications of the PDS are within the responsibility of the system supplier (see clause 8).

6.1.2 PDS input ratings

6.1.2.1 Input voltages and frequencies

The PDS input voltage and frequency rating shall be stated by the customer.

Standard values are as follows according to IEC 60038: 3 kV, 3,3 kV, 4,16 kV, 6 kV, 6,6 kV, 10 kV, 11 kV, 12,47 kV, 13,2 kV, 13,8 kV, (15 kV), 20 kV, 22 kV, 24,94 kV, 33 kV, 34,5 kV. Different, non-standard voltage values may be specified for system optimization or special circumstances.

6.1.2.2 Input currents

There are several input currents that shall be provided by the system supplier at rated line voltage and rated PDS load:

- the total r.m.s. current of the PDS – I_{LN} , it may include the current I_{XLN} required by auxiliaries if supplied on the same line, at the same voltage level as the PDS;
- the harmonic current spectrum of the PDS including the fundamental – I_{LNh} , h is up to 25 or 40;
- the currents required by auxiliaries including harmonics, if relevant, for each source – I_{XNj} .

These values shall be stated by the system supplier at the minimum specified a.c. line impedance (including the converter supply transformer), and with no background supply-voltage distortion.

6.1.3 PDS output ratings

6.1.3.1 Operating speed range

The operating speed range shall be defined using the following parameters:

- N_{min} = minimum operating speed
- N_o = base speed
- N_M = maximum operating speed.

Co-ordination is required between the system supplier and the driven equipment supplier regarding critical speeds (see 9.4.1).

6.1.3.2 Torque and power rating

Continuous output rating and possible overload capability of the PDS should be specified in terms of continuous and overload torque or power available at motor shaft at speeds defined above.

Co-ordination is required between the system supplier and the driven equipment supplier regarding torque pulsations (see 9.4).

6.1.3.3 Operating quadrants

The above ratings shall be given for all operating quadrants as agreed between system supplier and customer.

6.1.4 PDS efficiency and losses

The PDS subsystems included in the determination of the overall efficiency shall be stated. See clause 11 for the determination procedure.

NOTE All auxiliary losses (example: cooling system, excitation, control) are included in the PDS losses, as those of a self-ventilated motor.

The losses or efficiency of the PDS shall be specified by the system supplier at rated load and base speed. If guarantees are given, they shall always refer to rated values and rated conditions. In such a case, the following tolerances on power losses shall apply:

- total system 0 % +7 %
- converter 0 % +10 %
- transformer and motor 0 % +10 % according to their product standard
- other components according to their product standard if any,
or 0 % +10 % in other cases.

An example of variation of efficiency and losses versus speed is given in figure 9.

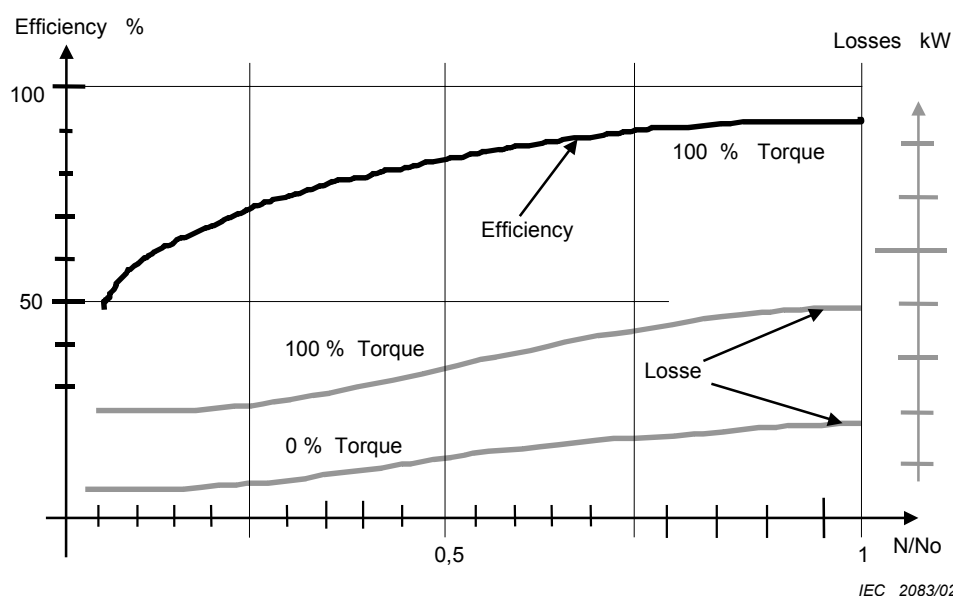


Figure 9 – Typical curves for efficiency and losses of a PDS at constant flux operation

6.1.5 PDS overload capability

Besides the rated value under continuous load conditions (see 6.1.2.2), the system supplier may assign additional values of the rated current, each under specified overload conditions, i.e. a converter equipment may be assigned by the system supplier different ratings for different types of load. The overload capability applies to the rated speed range.

The overload capability of the PDS can be specified as an intermittent load duty, or as repetitive load duty. A wider classification, as well as calculation methods can be found in IEC 61136-1. Special overload conditions should be agreed between the customer and the system supplier/component manufacturers.

For example, typical overload magnitudes and duration are given in table 3 of IEC 60146-1-1.

For any type of duty cycle, the r.m.s. value of the current over the complete cycle shall not exceed the rated current. Table 5 and figure 10 show three usual examples of a 1 min overload with a 10 min load cycle.

Table 5 – 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 ($t_s - t_{aM}$) min
1,5	1	0,928	9
1,25	1	0,968	9
1,1	1	0,988	9

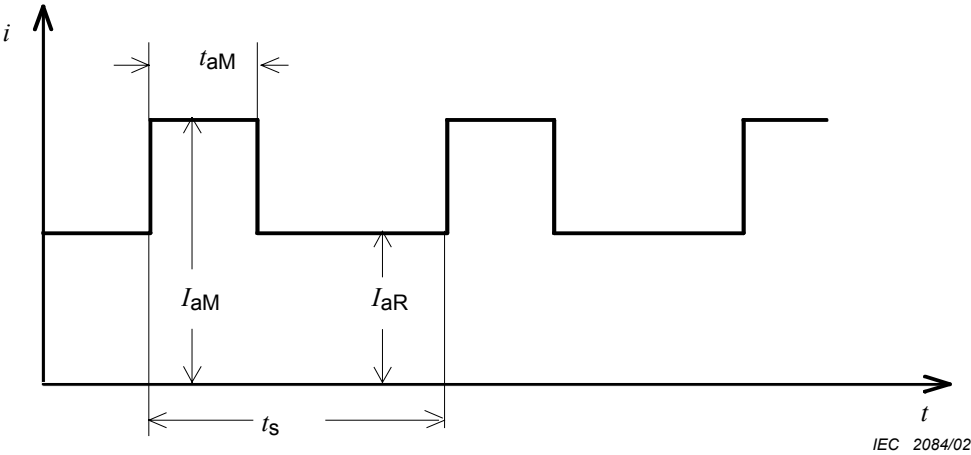


Figure 10 – Overload cycle example

For repetitive load duty, the rated fundamental converter current shall correspond, as a minimum, to the r.m.s. value of the motor current for a full period of the motor duty cycle and the overload capability of the converter shall be adequate for the load duty cycle.

For continuous duty, the rated fundamental converter current I_{aN1} shall correspond, as a minimum, to the continuous motor current necessary to supply the specified continuous motor torque. In the case of intermittent load duty, the overloads shall not cause the converter current to exceed its overload rating.

6.2 Converter

6.2.1 Converter input ratings

The converter manufacturer shall state the input voltage and frequency rating of the converter assembly. Standard values of the line frequency are 50 Hz or 60 Hz.

The input rated current shall be stated at rated line voltage and rated PDS load:

- the rated r.m.s. current of the converter input – I_{VN}