NEMA ICS 61800-4

ADJUSTABLE SPEED ELECTRICAL POWER DRIVE SYSTEMS

PART 4: GENERAL REQUIREMENTS — RATING SPECIFICATIONS FOR A.C. POWER DRIVE SYSTEMS ABOVE 1000 V A.C. AND NOT EXCEEDING 35 kV

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Adjustable Speed Electrical Power Drive Systems

Part 4: General Requirements—Rating Specifications for a.c. Power Drive Systems above 1000 V a.c. and Not Exceeding 35 kV

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Foreword

This document is an adaptation of the IEC Standard 61800-4 with the addition of requirements pertinent to use of these devices in the U.S. U.S. differences are indicated with (U.S. Differences) and italics.

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 61800-4 was prepared by IEC sub-committee 22G: Semiconductor power converters for adjustable speed electric drive systems, of IEC technical committee 22: Power electronic systems and equipment.

Annexes A, B and C are for information only.

The committee has decided that the contents of this publication will remain unchanged until 2008. At this date, the publication will be

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- withdrawn;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

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Section 1
GENERAL

1.1 SCOPE AND OBJECT

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.

U.S. NOTE: EMC Immunity and Emission requirements of IEC 61800-3 are not applicable within the U.S. 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.

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Section 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)

System with voltage above 1 kV (see figure 1) is an interconnected combination of equipment which provides a means of adjusting the speed of a mechanical load coupled to a motor. consisting of:

– power equipment (possible harmonic filters, input transformer, converter section, possible output transformer, a.c. motor);
– control, protection and auxiliaries;
– motor mounted auxiliary devices: encoders, tachometers, thermal switches and detectors, air blowers, heaters, and vibration sensors.

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.

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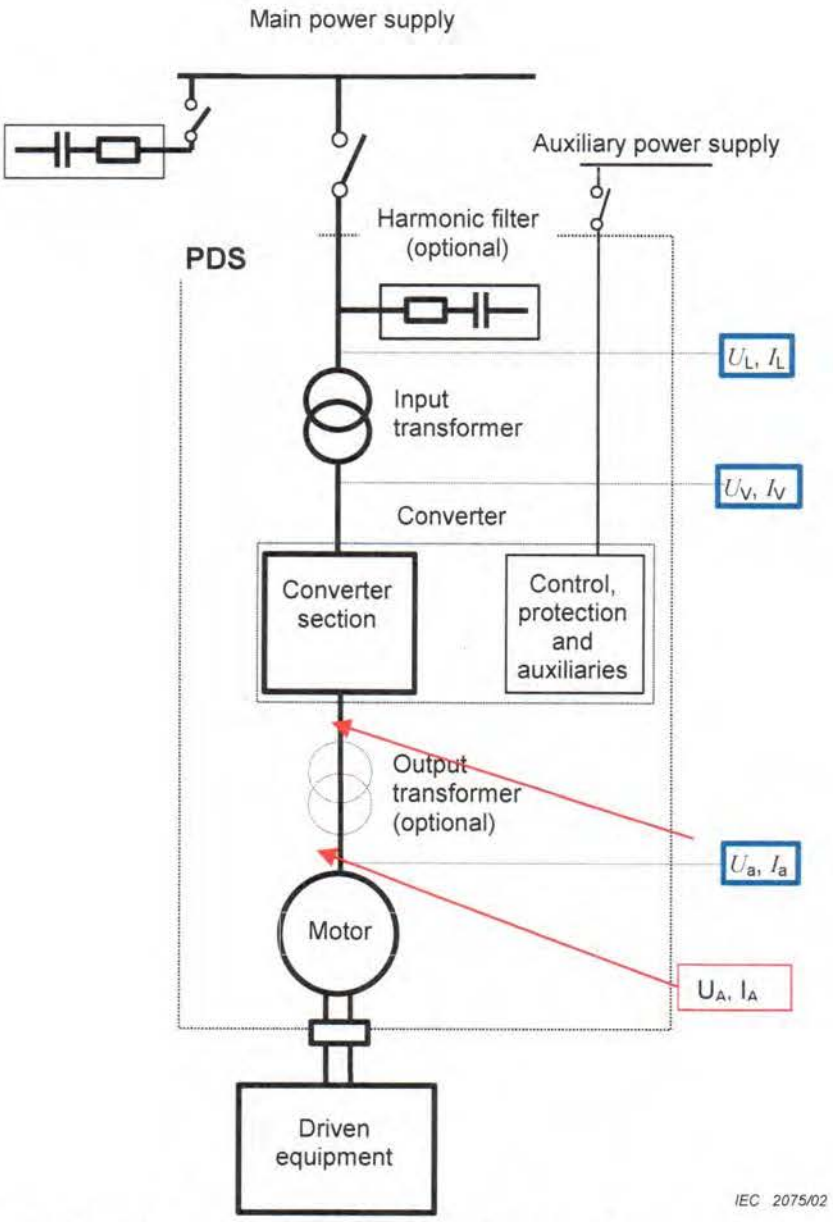


Figure 1 – Functional diagram of an a.c. adjustable speed power drive system (PDS), voltage above 1 kV

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.

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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.

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3.1.8
fundamental component (or fundamental)
the component whose frequency is the fundamental frequency example:

fundamental RMS current: The root mean square function of a periodically varying current waveform that contains no other function than a sinusoidal function. Such a periodically varying current waveform can be represented by the function:

$I(t) = I_p \sin(\omega t + \varphi)$, where I_p is the peak current in amperes, ω is the fundamental angular frequency in radians/second, t is time in seconds, and φ is the phase shift in radians. The fundamental RMS amperes is then defined as:

$$I_{RMS} = \sqrt{\frac{1}{T}\int_0^T I_p^2 \sin^2(\omega t + \varphi)dt}$$

Where $T = 2\pi/\omega$ seconds

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 IEV 551-20-05, IEV 551-20-07 and IEV 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 IEV 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) and18 fundamental periods (approximately 100 ms at 180 Hz).

3.1.13
harmonic content, *HC*
sum of the harmonic components of a periodic signal [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.

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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 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, $h = 6\,k \pm 1$ (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}

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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.

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

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

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,

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

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 ±15° 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:

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

NOTE 3: NEMA voltage unbalance (based on amplitude computation) gives a higher number than IEC voltage unbalance (based on fazorial computation), and τ the IEC simple approximation as above. See below:

NEMA voltage unbalance is defined as:
Voltage Unbalance = $[\ (V_{max} - V_{min}) / V_{avg}] \times 100$
where:
V_{max} = Maximum line-to-line voltage
V_{min} = Minimum line-to-line voltage
V_{avg} = Average of the three line-to-line voltages

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.

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3.3 CONVERTER

3.3.1
converter section (voltage above 1 kV)
electronic power converter employing semiconductors for the transformation of electric power to be supplied to a motor operating at voltage above 1 kV and not exceeding 35 kV according to figure 1. Examples:

rectifier: A converter that changes AC power to DC power.

inverter: A converter that changes DC power to AC power.

pulse-width modulated inverter (PWM): An inverter whose switching will vary the time duration of voltage or current for control of the output.

converter: A combination of the converter section, control protection and auxiliary circuit included on one chassis. The converter may include a disconnecting means. (See Figure 1-2-1.Converter)

3.3.2
converter input filter
circuits connected to the power input of the converter to reduce dv/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 dv/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.

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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.

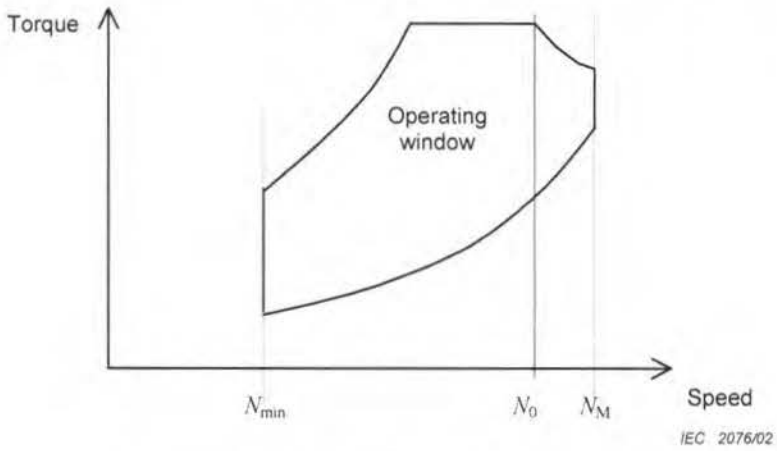


Figure 2 – Example of load envelope

3.4.2
minimum operating speed, N_{min}
minimum motor operating speed required by driven equipment.

3.4.3
maximum operating speed, N_{max}
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.

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Section 9
PDS INTEGRATION REQUIREMENTS

9.1 GENERAL CONDITIONS

9.1.1 Overview

In general, the PDS consists of the following main subsystems:

- transformer;
- converter section;
- control and protection;
- motor;
- harmonic filters (if needed).

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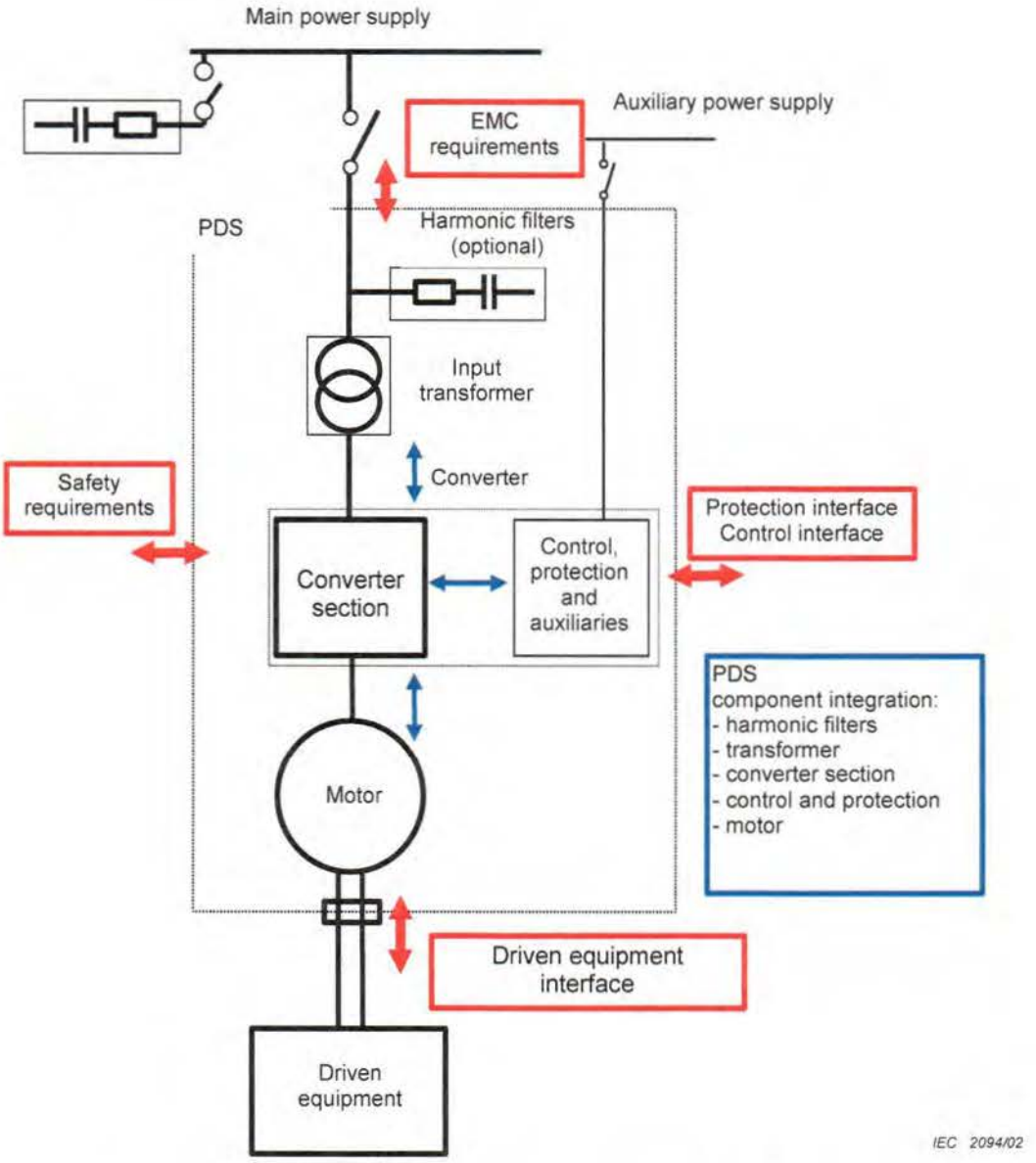


Figure 20 – Power drive system (PDS) – voltage above 1 000 V

9.2 SPECIAL CONDITIONS

9.2.1 Interactions between drive components

The installation of the PDS, consisting of its main components, in the location where it is intended to be used, requires a certain amount of know-how regarding both the correct operation of the PDS itself, and the interaction within its local environment. For a PDS whose voltage exceeds 1 kV a.c., special attention should be paid to the integration into the environment, in particular:

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- the main power supply;
- the main breaker;
- the main power cables;
- the EMC immunity and emissions;
- the civil installation;
- the driven machine;
- the auxiliary power supply;
- the main process control.

Within the PDS, special attention shall be paid to the interfaces and interference of the different subsystems in regard to:

- the system dimensioning;
- the safety requirements;
- the EMC according to internal requirements and IEC 61800-3;
- the possible interaction of subsystems.

The system supplier shall give all necessary information for the correct installation and cabling of the equipment. The general requirements for the integration of PDS are stated in the following subclauses.

9.2.2 Information to be exchanged

The system supplier shall give the necessary documentation for the customer of a PDS to allow the correct installation into a typical system or process. The customer and the system supplier shall agree at an early stage, if special measures have to be taken to achieve compliance with the EMC requirements of the dedicated environment.

The following information shall be made available to the system supplier:

- network impedance and structure (existing capacitor banks, filters, etc.);
- high voltage cable lengths;
- EMC information (actual distortion of the network);
- earthing conditions and specifications;
- information on driven equipment;
- safety requirements according to local regulations, for example colour coding.

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9.3 INTEGRATION OF COMPONENTS WITH VOLTAGES ABOVE 1,000 V

9.3.1 Overview

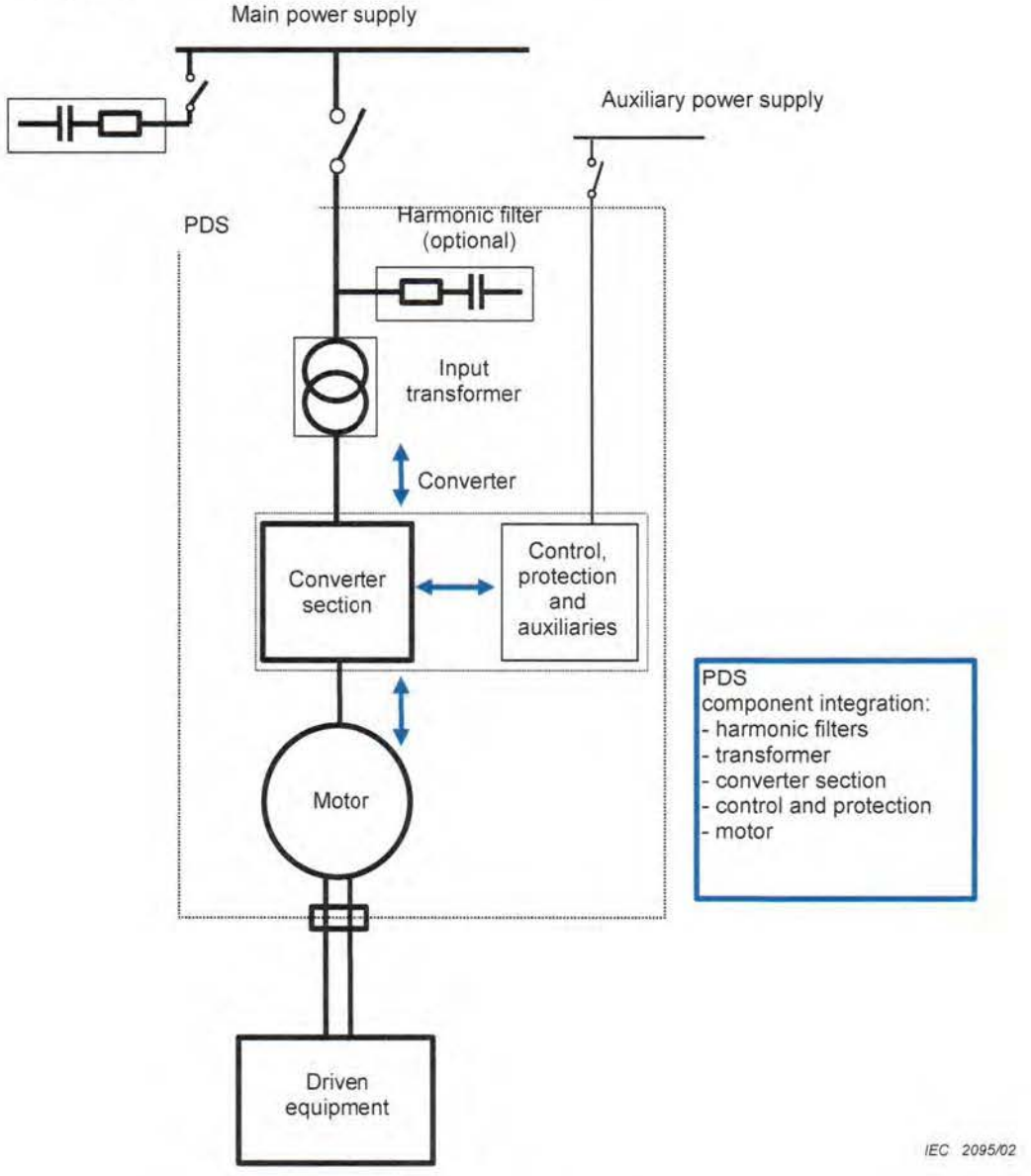


Figure 21 – PDS integration

9.3.2 Transformer integration

Additional overvoltage limitation shall be provided for main power supply transformers, (for example transient energy absorption as lightning arresters (LA)).

The energy of the non-repetitive transients caused by no-load switching of the main transformer feeding the converter assembly is related to the transformer magnetizing energy E. Under the

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assumption of a sinusoidal magnetizing current, the energy stored in the magnetizing impedance of the transformer can be calculated by the equation:

$$E = \frac{i_{mpu}}{4 \times \pi \times f_{LN}} \times S_N$$

where

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

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

S_N is the apparent power of the transformer (VA).

9.3.3 Earthing requirements

(U.S. Difference)

SYSTEM GROUNDING

The application of DC-linked converter systems requires that proper design consideration be given to the system grounding and the voltage ratings of isolation transformers, the motor, and the power converter. An improperly grounded system can result in ground currents circulating between the source and the motor through the power converter. Higher than normal voltage to ground may occur at the terminals of the isolation transformer or the motor. These voltages are caused by common mode voltage generated by the power converter system, which displaces system neutral voltage from ground potential.

The motor terminal-to-ground voltage can be reduced by:

a. Isolating the installation electrical system ground with a transformer.
b. Utilizing separate reactors in both the positive and negative DC link.
c. Connecting the motor neutral to ground through impedance.

If this design practice is properly followed, motor neutral-to-ground voltage can be reduced to near zero. The drive isolation transformer insulation system should be designed for voltage to ground which may exceed rated line-to-line voltage of the secondary winding. Consult the converter equipment supplier for the specific voltage to ground insulation levels required for the motor and isolation transformer.

9.3.3.1 Equipotential bonding of main components

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

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

The protective bonding circuit and the equipotential bonding (its interconnection) between main components should be considered. Typically it is also necessary to take into account local requirements. The protective bonding concept should be agreed upon between system supplier and customer. It should cover the whole PDS, including:

- the transformer;
- the main converter;
- the motor.

The following items are important examples:

- the material of the protective bonding;

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and the output converter(s) if any, or between the converter and the motor shall be defined for power transmission including the effects of the harmonic content of the current. The design should take into account reflections, possible capacitive coupling, magnetic coupling or radiation.

Cables should preferably be put in parallel by the use of multi-phase cables. Where such appropriate cables are not available, the use of single core cables is possible provided that the multi-phase system is physically constituted for each unit of parallel cables.

9.4 PROTECTION INTERFACE

The PDS should contain the necessary protection functions, system components protection and a generally high system availability. Well-designed protection will protect against contingencies internal and external to the drive system. This should include the protections listed in table 8.

9.4.a POSITIVE BLOCKING (coming from ICS 7, Part 1, Clause 7.3)(U.S. Difference)

For equipment covered in Part 5 and 6, and except for applications in which the operator does not have access to the driven motor, the manually-operated STOP command of the controller or a separate ON and OFF switch shall provide a positive means of blocking rotational power to the motor from the line.

The intent of subclause 7.3 is to minimize the hazards to personnel from an unexpected motion of the motor or driven equipment due to malfunction of a control element or power semiconductor.

9.5 BASIC SYSTEM PROTECTION

The exact requirements for protection of the system depend on the mission and configuration of the drive system. General requirements are defined by NFPA 70. Overload and other overcurrent protection, which generally allow for the safe operation of the equipment, is required by NFPA 70 for motors, capacitor banks, isolation transformers and motor converters. However, to fully protect the equipment from damage caused by other contingencies, additional protection is recommended.

A well-designed system provides protection against contingencies internal and external to the drive system. These may include:

Power source irregularities

1) *Voltage surges*
2) *Over and under voltage*
3) *Phase reversal*
4) *Voltage unbalance*

Overcurrent conditions

1) *Fault currents*
2) *Ground currents*
3) *Internal faults*

Overloads

Equipment overtemperature

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Motor overspeed

Excessive vibration of machine

Lost lubrication of machine

Power converter protection

Power converters are protected by internal solid-state circuits for common faults. Most contingencies will cause the converter to take gate protective action which will force the internal currents and the motor current to zero. This is sufficient as long as the converter components have not failed. In the event of a component failure, the converter should signal the line protective circuit breaker or contactor to trip.

9.6 MOTOR PROTECTION

Motors and motor branch circuits are effectively protected by apparatus in the motor starter or power converter, using relay devices that sequence the converter. Although NFPA 70 requires only overcurrent and overload protection, it is highly recommended that there be means of detecting winding overtemperature, bearing overtemperature, bearing vibration, and differential current in motors rated over 500 horsepower.

Surge protection for motors can be provided by surge arresters and capacitors. The possible effect of the surge capacitor on the converter must be determined to assure satisfactory operation.

Special consideration should be given to protecting induction motors against self-excitation in drives employing large capacitor banks or filters connected between the power converter and the motor. Where the kVAR rating of the capacitor bank exceeds 20 percent to 30 percent of the kVA rating of the motor, it can become self-excited which may result in higher than normal voltage across the motor terminals. Appropriate means should be considered to prevent self-excitation when power is lost. For example, capacitor banks and harmonic filters should be disconnected from motor.

9.7 TRANSFORMER PROTECTION

Isolation transformer protection is typically provided by relays acting through a protective circuit breaker device or to remote alarms. Overcurrent protection in the transformer primary circuit is required by NFPA 70. Ground-fault and differential-current protection are commonly provided on larger units. Care should be taken in selecting relays for this application, taking into consideration adjustable-frequency drive harmonics. Surge protection is typically provided on the primary of isolation transformers. When properly coordinated, such surge protection can protect the entire drive system from line voltage surges caused by lighting and switchgear.

9.7.a HARMONIC FILTERS AND CAPACITOR BANKS

Harmonic filters and capacitor banks require overcurren protection, which is typically provided by fuses. Voltage or current unbalance protection is also commonly provided. See NFPA 70 for further information regarding protection.

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Table 8 – PDS protection functions

Line-side supply	Alarm	Trip	Remark
Outage, phase loss	X	X	
Line overvoltages	X	X	
Line under-voltages	X	X	
Line voltage unbalance	X	X	
Line feeder	**Alarm**	**Trip**	**Remark**
Over-current		X	
Overload	X	X	
Transformer	**Alarm**	**Trip**	**Remark**
Gas relay (Buchholz)	X	X	oil-type only
Over-temperature	X	X	
Loss of cooling media	X	X	
Low oil level	X		oil-type only
Converter	**Alarm**	**Trip**	**Remark**
Overcurrent	X	X	commutation failure, short circuit, etc.
Overload	X	(X)	thermal
Overvoltage	X	X	
Ground fault	X	(X)	
Loss of cooling	X	(X)	
Over-temperature	X	(X)	
Loss of auxiliary supply	X	X	
Loss of communication to process control	X	(X)	
Loss of speed feedback	X		
Motor	**Alarm**	**Trip**	**Remark**
Motor over/under-voltage	X	X	
Motor overcurrent	X	X	
Overload	X	(X)	thermal
Over-speed	X	X	
Winding over-temperature	X	X	
Bearing over-temperature	X	X	
High vibrations	X	X	
Loss of cooling	X	(X)	
Loss of lubrication	X	X	

NOTE 1 Vibration protection functions can be taken care of by the driven equipment supplier.

NOTE 2 (X): conditionally applied.

NOTE 3 The impedance of the supply network at the IPC (see 5.1.1.2), and the input impedances of the PDS (see 8.2.3) shall be considered.

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