

Adjustable speed electrical power drive systems —

Part 5-1: Safety requirements — Electrical, thermal and energy

The European Standard EN 61800-5-1:2003 has the status of a
British Standard

ICS 29.130

National foreword

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

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Adjustable speed electrical power drive systems
Part 5-1: Safety requirements -
Electrical, thermal and energy
(IEC 61800-5-1:2003)

Entraînements électriques de puissance
à vitesse variable
Partie 5-1: Exigences de sécurité -
Electrique, thermique et énergétique
(CEI 61800-5-1:2003)

Elektrische Leistungsantriebssysteme
mit einstellbarer Drehzahl
Teil 5-1: Anforderungen an die Sicherheit -
Elektrische, thermische und energetische
Anforderungen
(IEC 61800-5-1:2003)

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European Committee for Electrotechnical Standardization
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Foreword

The text of document 22G/108/FDIS, future edition 1 of IEC 61800-5-1, 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 61800-5-1 on 2003-03-01.

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Annexes designated "normative" are part of the body of the standard.

Annexes designated "informative" are given for information only.

In this standard, annexes C and ZA are normative and annexes A, B, D and E are informative.

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61800-5-1:2003 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 61082	NOTE	Harmonized as EN 61082 series (not modified).
IEC 62079	NOTE	Harmonized as EN 62079:2001 (not modified).

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ADJUSTABLE SPEED ELECTRICAL POWER DRIVE SYSTEMS –

Part 5-1: Safety requirements – Electrical, thermal and energy

1 Scope

This part of IEC 61800 specifies requirements for adjustable speed power drive systems, or their elements, with respect to electrical, thermal and energy safety considerations. It does not cover the driven equipment except for interface requirements. It applies to adjustable speed electric drive systems which include the power conversion, drive control, and motor or motors. Excluded are traction and electric vehicle drives. It applies to d.c. drive systems connected to line voltages up to 1 kV a.c., 50 Hz or 60 Hz and a.c. drive systems with converter input or output voltages up to 35 kV, 50 Hz or 60 Hz.

Rating specifications for d.c. power drive systems connected to line voltages up to 1 kV a.c. are covered in IEC 61800-1.

Rating specifications for a.c. power drive systems with converter input or output voltages up to 1 kV a.c. are covered in IEC 61800-2.

EMC aspects are covered in IEC 61800-3.

Rating specifications for a.c. power drive systems with converter input or output voltages greater than 1 kV a.c. and up to 35 kV a.c. are covered in IEC 61800-4.

The scope of this part of IEC 61800 does not include devices used as component parts of a PDS if they comply with the safety requirements of a relevant product standard for the same environment.

NOTE 1 In some cases, safety requirements of the overall PDS (for example, protection against direct contact) can necessitate the use of special components and/or additional measures.

NOTE 2 For the purposes of this International Standard, energy hazards can be, for example, explosion of components or stored energy in capacitors.

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 (all parts), *Rotating electrical machines*

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

IEC 60050(151), *International Electrotechnical Vocabulary – Chapter 151: Electrical and magnetic devices*

IEC 60050(161), *International Electrotechnical Vocabulary – Chapter 161: Electromagnetic compatibility*

IEC 60050(191), *International Electrotechnical Vocabulary – Chapter 191: Dependability and quality of service*

IEC 60050(441), *International Electrotechnical Vocabulary – Chapter 441: Switchgear, controlgear and fuses*

IEC 60050(442), *International Electrotechnical Vocabulary – Part 442: Electrical accessories*

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

IEC 60050(601), *International Electrotechnical Vocabulary – Chapter 601: Generation, transmission and distribution of electricity – General*

IEC 60060-1:1989, *High-voltage test techniques. Part 1: General definitions and test requirements*

IEC 60071-1:1993, *Insulation co-ordination – Part 1: Definitions, principles and rules*

IEC 60071-2:1996, *Insulation co-ordination – Part 2: Application guide*

IEC 60112:1979, *Method for determining the comparative and the proof tracking indices of solid insulating materials under moist conditions*

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

IEC 60249-1:1982, *Base materials for printed circuits – Part 1: Test methods*

IEC 60364-1:2001, *Electrical installations of buildings – Part 1: Fundamental principles, assessment of general characteristics, definitions*

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

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

IEC 60617: *Graphical symbols for diagrams*

IEC 60664-1:1992, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*²

¹ There is a consolidated edition 2.1 (2001) that includes edition 2.0 and its Amendment 1.

² There is a consolidated edition 1.2 (2002) that includes edition 1.0 and its Amendments 1 and 2.

IEC 60664-3:1992, *Insulation coordination for equipment within low-voltage systems – Part 3: Use of coatings to achieve insulation coordination of printed board assemblies*

IEC 60695-2-10:2000, *Fire hazard testing – Part 2-10: Glowing/hot-wire based test methods – Glow-wire apparatus and common test procedure*

IEC 60695-2-11:2000, *Fire hazard testing – Part 2-11: Glowing/hot-wire based test methods – Glow-wire flammability test method for end products*

IEC 60695-2-12:2000, *Fire hazard testing – Part 2-12: Glowing/hot-wire based test methods – Glow-wire flammability test method for materials*

IEC 60695-2-13:2000, *Fire hazard testing – Part 2-13: Glowing/hot-wire based test methods – Glow-wire ignitability test method for materials*

IEC 60695-11-10:1999, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

IEC 60695-11-20:1999, *Fire hazard testing – Part 11-20: Test flames – 500 W flame test methods*

IEC 60707:1999, *Flammability of solid non-metallic materials when exposed to flame sources – List of test methods*

IEC 60755:1983, *General requirements for residual current operated protective devices*

IEC 60947-7-1:2002 *Low-voltage switchgear and control gear – Part 7-1: Ancillary equipment – Terminal blocks for copper conductors*

IEC 60947-7-2:2002, *Low-voltage switchgear and controlgear – Part 7-2: Ancillary equipment – Protective conductor terminal blocks for copper conductors*

IEC 60990:1999, *Methods of measurement of touch current and protective conductor current*

IEC 61800-1:1997, *Adjustable speed electrical power drive systems – Part 1: General requirements – Rating specifications for low voltage adjustable speed d.c. power drive systems*

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*

IEC 61800-4:2002, *Adjustable speed electrical power drive systems – Part 4: General requirements – Rating specifications for a.c. power drive systems above 1 000 V and not exceeding 35 kV*

ISO 3864:1984, *Safety colours and safety signs*

3 Terms and definitions

For the purposes of this part of IEC 61800, the terms and definitions given in chapters 111, 151, 161, 191, 441, 442, 551 and 601 of IEC 60050, IEC 60664-1, Parts 1 to 4 of IEC 61800 (some of which are repeated below for convenience) and the following definitions apply.

3.1 System

3.1.1

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. (see Figure 1)

3.1.2

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 (see Figure 1)

3.1.3

installation

equipment or equipments which include at least both the PDS (see 3.1.4) and the driven equipment (see Figure 1)

3.1.4

power drive system (PDS)

power drive system, including the CDM and the motor but not the driven equipment (see Figure 1)

3.2 General

3.2.1

auxiliary circuit

circuit supplying an element or elements of a PDS other than the main motor which exchanges mechanical power with the driven equipment

NOTE Examples of auxiliary circuits are interface, control, cooling, measurement and independent field supply circuit of the main motor.

3.2.2

basic insulation

insulation applied to live parts to provide basic protection against electrical shock

[VEI 826-03-17, modifié]

3.2.3

closed electrical operating area

room or location for electrical equipment to which access is restricted to skilled or instructed persons by the opening of a door or the removal of a barrier by the use of a key or tool and which is clearly marked by appropriate warning signs

3.2.4

comparative tracking index (CTI)

numerical value of the maximum voltage in volts at which a material withstands 50 drops without tracking

NOTE 1 The value of each test voltage and the CTI should be divisible by 25.

[IEC 60112: 1979, definition 2.3]

3.2.5

conditionally short-circuit proof

circuit in which only prescribed protective devices such as fuses, switches, electronic interlocks, or electronic current limiters respond when subjected to a short-circuit

3.2.6

decisive voltage class

calculated voltage range used to determine the classification of protective measures against electric shock

3.2.7

double insulation

insulation comprising both basic insulation and supplementary insulation

[VEI 826-03-19, modified]

NOTE Basic and supplementary insulation are separate, each designed for basic protection against electric shock.

3.2.8

electrical breakdown

failure of insulation under electric stress when the discharge completely bridges the insulation, thus reducing the voltage between the electrodes almost to zero

[IEC 60664-1:1992, definition 1.3.20]

3.2.9

ELV (Extra Low Voltage)

any voltage not exceeding 50 V a.c. r.m.s. and 120 V d.c.

NOTE RMS ripple voltage of not more than 10 % of the d.c. component.

3.2.10

FELV (Functional ELV) circuit

electrical circuit in which the voltage does not exceed ELV, and which does not comply with the safety requirements for SELV (see 3.2.29) or PELV (see 3.2.16) circuits

3.2.11

functional insulation

insulation between conductive parts which does not provide protection against electric shock

3.2.12

high-voltage product

product with rated supply voltage between 1 kV and 35 kV a.c., 50 Hz or 60 Hz

NOTE These products fall into the scope of IEC 61800-4

3.2.13

(earth) leakage current

current flowing from the live parts of the installation to earth, in the absence of an insulation fault

[IEV 442-01-24]

3.2.14

live part

conductor or conductive part intended to be energized in normal use, including a neutral conductor but not a protective earth neutral

3.2.15

low-voltage product

product with rated supply voltage up to 1 000 V a.c., 50 Hz or 60 Hz

NOTE These products fall into the scope of IEC 61800-1 or IEC 61800-2.

3.2.16

PELV (Protective ELV) circuit

electrical circuit with the following characteristics:

- the voltage does not exceed ELV; and
- protective separation from circuits other than PELV or SELV; and
- provisions for earthing of the PELV circuit, or its exposed conductive parts, or both

3.2.17

professional equipment

equipment for use in trades, professions, or industries and which is not intended for sale to the general public. The designation is specified by the manufacturer.

[IEC 61000-3-2: 2000, definition 3.15]

3.2.18

protective bonding

electrical connection to earth of conductive parts for safety purposes

3.2.19

protective class 0

equipment in which protection against electric shock relies only upon basic insulation

NOTE Equipment of this class becomes hazardous in the event of a failure of the basic insulation.

3.2.20

protective class I

equipment in which protection against electric shock does not rely on basic insulation only, but which includes an additional safety precaution in such a way that means are provided for the connection of accessible conductive parts to the protective (earthing) conductor in the fixed wiring of the installation, so that accessible conductive parts cannot become live in the event of a failure of the basic insulation

3.2.21

protective class II

equipment in which protection against electric shock does not rely on basic insulation only, but in which additional safety precautions such as double insulation or reinforced insulation are provided, there being no provision for protective earthing or reliance upon installation conditions

3.2.22

protective class III

equipment in which protection against electric shock relies on supply at SELV and in which voltages higher than those of SELV are not generated

3.2.23

protective conductor

conductor providing protection against electric shock by connecting conductive parts to earth

3.2.24

protective earthing (PE)

earthing of a point in a system, or equipment, for protection against electric shock in case of a fault

3.2.25

protective impedance

an impedance connected between live parts and exposed conductive parts, of such value that the current, in normal use and under likely fault conditions, is limited to a safe value, and which is so constructed that its reliability is maintained throughout the life of the equipment

[IEV 442-04-24, modified]

3.2.26

protective screening

separation of circuits from hazardous live-parts by means of an interposed conductive screen, connected to the means of connection for an external protective conductor

3.2.27

protective separation

separation between circuits by means of basic and supplementary protection (basic insulation plus supplementary insulation or protective screening) or by an equivalent protective provision (e.g. reinforced insulation)

3.2.28

reinforced insulation

single insulation system, applied to live parts, which provides a degree of protection against electric shock equivalent to double insulation under the conditions specified in the relevant IEC standard

[IEC 60664-1: 1992, definition 1.3.17.5]

3.2.29

SELV (Safety ELV) circuit

electrical circuit with the following characteristics:

- the voltage does not exceed ELV; and
- protective separation from circuits other than SELV or PELV; and
- no provisions for earthing of the SELV circuit, or its exposed conductive parts; and
- basic insulation of the SELV circuit from earth and from PELV circuits

3.2.30

supplementary insulation

independent insulation applied in addition to basic insulation in order to provide protection against electric shock in the event of a failure of basic insulation

[IEC 60664-1: 1992, definition 1.3.17.3]

NOTE Basic and supplementary insulation are separate, each designed for basic protection against electric shock.

3.2.31

system voltage

voltage used to determine insulation requirements

- for low voltage earthed systems: the r.m.s. value of the rated voltage between a phase and earth
- for low voltage non-earthed three-phase systems: the r.m.s. value of the rated voltage between a phase and an artificial neutral point (an imaginary junction of equal impedances from each phase)

NOTE For most systems, this is equivalent to dividing the phase-to-phase voltage by $\sqrt{3}$

- for low voltage non-earthed single-phase a.c. or d.c. systems: the r.m.s. value of the rated voltage between the phases
- for high voltage systems, the r.m.s. value of the rated voltage between phases

3.2.32

temporary overvoltage

overvoltage at the supply frequency of relatively long duration

[IEC 60664-1:1992, definition 1.3.7.1]

3.2.33

user terminal

terminal provided for connection to be made during installation

3.2.34

working voltage

voltage, at rated supply conditions (without tolerances) and worst case operating conditions, which occurs by design in a circuit or across insulation

NOTE The working voltage can be d.c. or a.c. Both the r.m.s. and recurring peak values are used.

3.3 Test classification

3.3.1

type test

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

[IEV 151-04-15]

3.3.2

routine test

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

[IEV 151-04-16]

3.3.3

sample test

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

[IEV 151-04-17]

3.3.4

commissioning test

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

[IEV 151-04-21]

3.3.5

special test

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

3.3.6

acceptance test

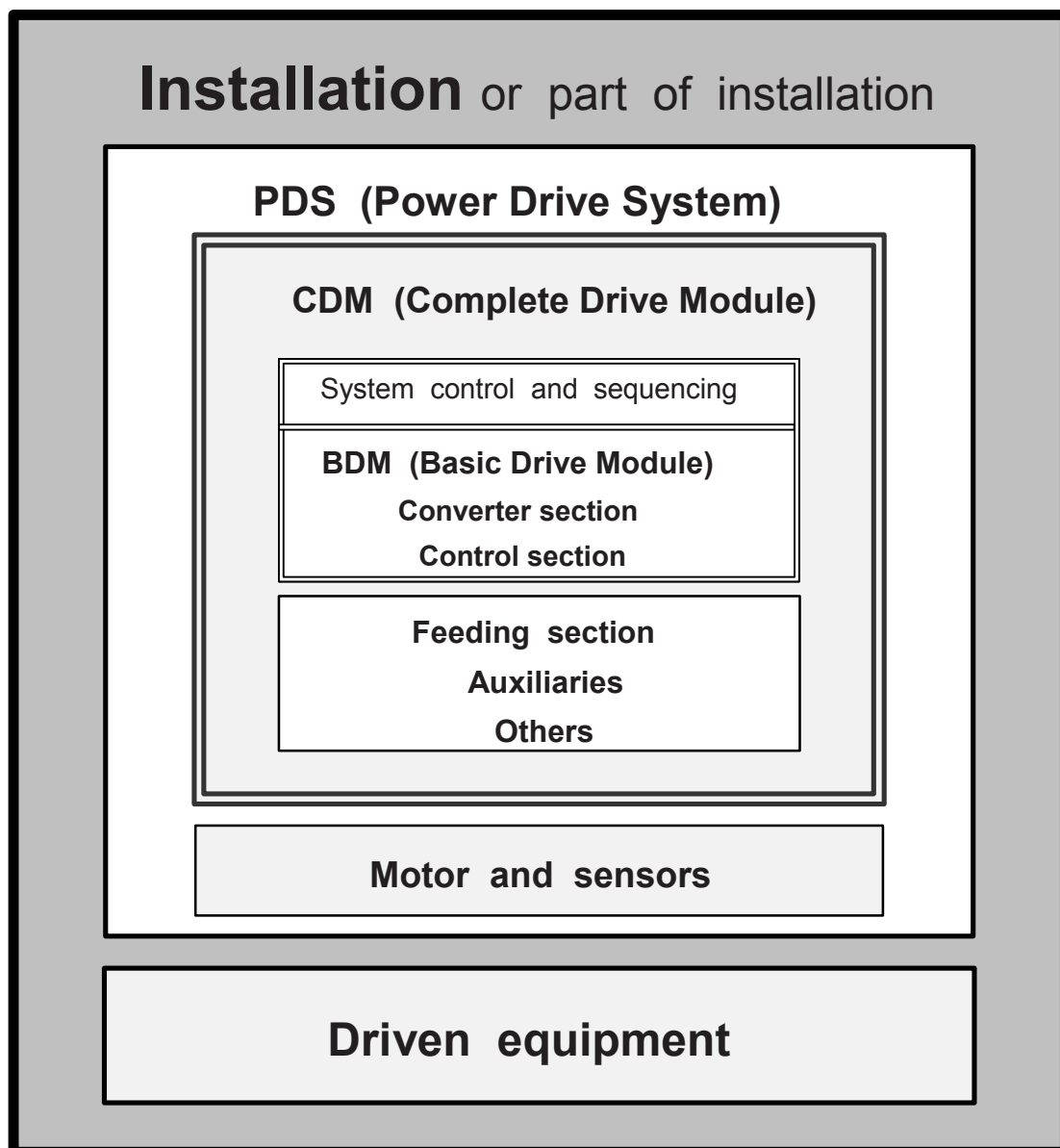
contractual test to prove to the customer that the device meets certain conditions of its specification

[IEV 151-04-20]

3.3.7

witness test

any of the above tests performed in the presence of the customer, the user, or his representative



IEC 257/03

Figure 1 – PDS hardware configuration within an installation

4 Protection against electric shock, thermal, and energy hazards

4.1 General

This clause 4 defines the minimum requirements for the design and construction of a PDS. Protection against electric shock shall be maintained in single fault conditions as well as under normal conditions.

The design of a PDS shall also be such that it has the strength and rigidity to resist any reasonably foreseeable misuse associated with its intended application without total or partial collapse resulting in a risk of fire, electric shock, or other hazards.

PDS shall be designed to avoid operating modes or sequences that may lead to component failure.

Circuit analysis shall be performed on other than SELV and PELV circuits of PDS to identify components whose failure would result in a fire or electric shock hazard. The analysis shall include the effect of short-circuit and open-circuit conditions of the component. The analysis shall not include power semiconductor devices, when equivalent testing is accomplished during short-circuit tests, or components which have been independently evaluated. See 5.2.3.8 for test.

NOTE It is possible that no critical components will be revealed by the analysis. In this case, no component failure testing is required.

Consideration shall be given to potential safety hazards associated with major component parts of the PDS, such as motor rotating parts and flammability of transformer and capacitor oils.

4.2 Protection against electric shock

4.2.1 Decisive voltage class

4.2.1.1 Use of decisive voltage class

Protective measures against electric shock depend on the decisive voltage classification of the circuit according to Table 1, which correlates the limits of the working voltage within the circuit with the decisive voltage class. The decisive voltage class in turn indicates the minimum required level of protection for the circuit.

Table 1 – Summary of the limits of the decisive voltage classes

Decisive voltage class	Limits of working voltage V			Subclause
	a.c. voltage (r.m.s.)	a.c. voltage (peak)	d.c. voltage (mean)	
	U_{ACL}	U_{ACPL}	U_{DCL}	
A ^a	30	42,4	60	4.2.4.2, 4.2.4.4
B	50	71	120	4.2.5.3 a), b)
C	1 000	4 500 ^b	1 500	
D	>1 000	>4 500 ^b	>1 500	
^a For equipment having more than one decisive voltage class A circuit, the r.m.s. and peak voltages shall not exceed 25 V and 35,4 V respectively. ^b The value of 4 500 V allows all low-voltage products to be covered by Table 4 (possible reflections up to $3 \times \sqrt{2} \times 1\,000\text{ V} = 4\,242\text{ V}$).				

4.2.1.1.1 Circuits of decisive voltage class A

Circuits of decisive voltage class A do not require:

- protection against direct contact, or
- protective bonding of exposed conductive parts

They require:

- at least basic insulation from circuits of decisive voltage class B
 - protective separation from circuits of decisive voltage class C (if protection against direct contact is not provided), or
 - basic insulation from circuits of decisive voltage class C (if protection against direct contact is provided by supplementary insulation for the higher voltage circuit)
- protective separation from circuits of decisive voltage class D

4.2.1.1.2 Circuits of decisive voltage class B

Circuits of decisive voltage class B do not require:

- protective bonding of exposed conductive parts

They require:

- protection against direct contact
- at least basic insulation from other circuits of decisive voltage class B
- protective separation from circuits of decisive voltage class C (if protection against direct contact is provided by basic insulation for the decisive voltage class B circuit), or
- basic insulation from circuits of decisive voltage class C (if protection against direct contact is provided by supplementary insulation for the higher voltage circuit)
- protective separation from circuits of decisive voltage class D

4.2.1.1.3 Circuits of decisive voltage class C

Circuits of decisive voltage class C require:

- protection against direct contact
- protective separation from circuits of decisive voltage class D
- at least basic insulation from other circuits of decisive voltage class C
- protective bonding or double or reinforced insulation of exposed conductive parts

4.2.1.1.4 Circuits of decisive voltage class D

Circuits of decisive voltage class D require:

- protection against direct contact, and
- at least basic insulation from other circuits of decisive voltage class D, and
- protective bonding or double or reinforced insulation of exposed conductive parts.

4.2.1.2 Circuit evaluation

4.2.1.2.1 General

The decisive voltage classification of a given circuit is evaluated by the method set out below, three cases of waveforms being considered.

4.2.1.2.2 AC working voltage (see Figure 2)

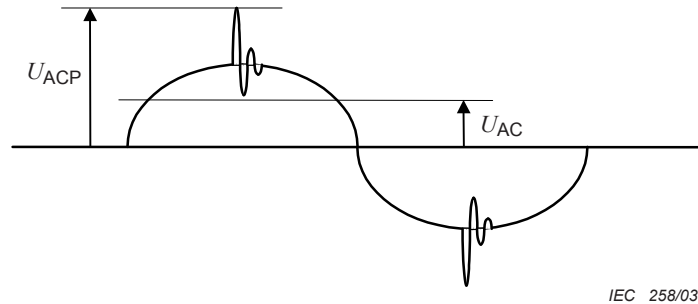


Figure 2 – Typical waveform for a.c. working voltage

The working voltage has an r.m.s. value of U_{AC} and a recurring peak value of U_{ACP} .

The decisive voltage class is that of the lowest voltage row of Table 1 for which both of the following conditions are satisfied.

- $U_{AC} \leq U_{ACL}$
- $U_{ACP} \leq U_{ACPL}$

4.2.1.2.3 DC working voltage (see Figure 3)

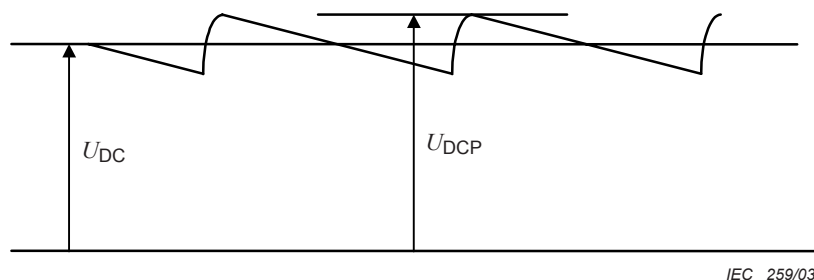


Figure 3 – Typical waveform for d.c. working voltage

The working voltage has a mean value of U_{DC} and a recurring peak value of U_{DCP} , caused by a ripple voltage of r.m.s. value not greater than 10 % of U_{DC} .

The decisive voltage class is that of the lowest voltage row of Table 1 for which both of the following conditions are satisfied.

- $U_{DC} \leq U_{DCL}$
- $U_{DCP} \leq 1,17 \times U_{DCL}$

4.2.1.2.4 Pulsating working voltage (see Figure 4)

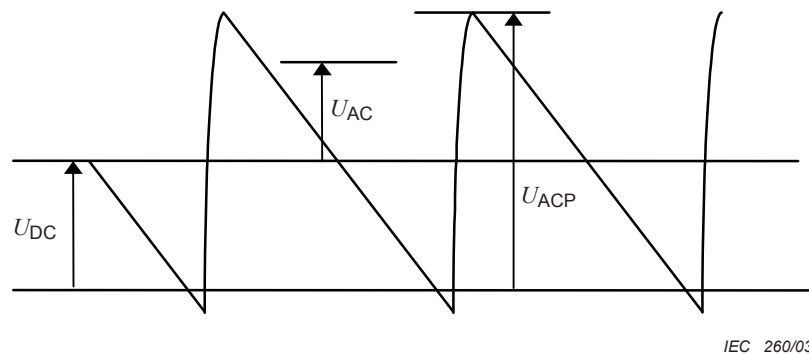


Figure 4 – Typical waveform for pulsating working voltage

The working voltage has a mean value of U_{DC} and a recurring peak value of U_{ACP} , caused by a ripple voltage of r.m.s. value U_{AC} greater than 10 % of U_{DC} .

The decisive voltage class is that of the lowest voltage row of Table 1 for which both of the following conditions are satisfied.

- $U_{AC}/U_{ACL} + U_{DC}/U_{DCL} \leq 1$
- $U_{ACP}/U_{ACPL} + U_{DC}/(1,17 \times U_{DCL}) \leq 1$

4.2.2 Protective separation

Protective separation is required at all the following interfaces:

- between ELV circuits according to 4.2.4.2 (SELV or PELV) and circuits other than those according to 4.2.4;
- between circuits of decisive voltage class D and circuits with a lower decisive voltage class.

Protective separation of the circuits shall be achieved by application of materials resistant to ageing and environmental contamination, as well as by special constructive measures; and

- by double or reinforced insulation, or;
- by protective screening, i.e. by a conductive screen connected to the protective bonding of the PDS, or connected to the protective earth conductor itself, whereby the screen is separated from live parts by at least basic insulation, or;
- by protective impedance according to 4.2.4.3 comprising limitation of discharge energy and of current, or by limitation of voltage according to 4.2.4.4.

Protective separation shall be implemented at all interfaces between the above-stated circuits.

The protective separation shall be fully and effectively maintained under all conditions of intended use of the PDS.

4.2.3 Protection against direct contact

4.2.3.1 General

Protection against direct contact is employed to prevent persons from touching live parts which do not meet the requirements of 4.2.4. It shall be provided by one or more of the measures given in 4.2.3.2 and 4.2.3.3.

Any conductive part which is not separated from the live parts by at least basic insulation shall be considered to be a live part.

A metallic accessible part is considered to be conductive, if its surface is bare or is covered by an insulating layer which does not comply with the requirements of basic insulation.

4.2.3.2 Protection by means of insulation of live parts

Live parts shall be completely surrounded with permanent insulation if their working voltage is greater than the maximum limit of decisive voltage class A or if they do not have protective separation from adjacent circuits of decisive voltage class B, C or D. The insulation shall be rated according to the impulse voltage, temporary overvoltage or working voltage (see 4.2.6.3.1), whichever gives the most severe requirement.

As an alternative to solid insulation, a clearance according to 4.2.6.6, shown by L_1 and L_2 in Figure 5, may be provided.

The grade of insulation – basic, double or reinforced – depends on:

- the decisive voltage class of the live parts or adjacent circuits, and
- the connection of conductive parts to protective bonding.

Examples of insulation configurations are given in Figure 5, which also shows the requirements for apertures.

Three cases are considered:

Case a) Accessible parts are conductive and are connected to protective bonding.

- Basic insulation is required between accessible parts and the live parts. The relevant voltage is that of the live parts (see Figure 5, cells 1)a), 2)a), 3)a)).

Cases b) and c) Accessible parts are non-conductive (case b)) or conductive but not connected to protective bonding (case c)). The required insulation is:

- Double or reinforced insulation between accessible parts and live parts of decisive voltage class C or D. The relevant voltage is that of the live parts (see Figure 5, cells 1)b), 1)c), 2)b), 2)c)).
- Supplementary insulation between accessible parts and live parts of circuits of decisive voltage class A or B which are separated by basic insulation from adjacent circuits of decisive voltage class C. The relevant voltage is the highest voltage of the adjacent circuits (see Figure 5, upper cells 3)b), 3)c)).
- Basic insulation between accessible parts and live parts of circuits of decisive voltage class B which have protective separation from adjacent circuits of decisive voltage class C or D. The relevant voltage is that of the live parts (see Figure 5, lower cells 3)b), 3)c)).

Solid insulation shall be tested by performing the impulse voltage test of 5.2.3.1, the a.c. or d.c. voltage test of 5.2.3.2 and the partial discharge test of 5.2.3.3, as appropriate. The compliance of clearances shall be verified by visual inspection and if necessary by performing the impulse voltage test of 5.2.3.1 and the a.c. or d.c. voltage test of 5.2.3.2.

Type of insulation	Insulation configuration		
	a Accessible parts conductive and connected to protective bonding	b Accessible parts not conductive	c Accessible parts conductive, but NOT connected to protective bonding
1) Solid or liquid			
2) Totally or partially by air clearance			
3) Insulation for adjacent circuits: Circuit A: lower voltage circuit Circuit C: higher voltage circuit; upper row – class C only, lower row – class C or D			
4) Requirements for apertures in enclosures			
A live part	L_1 clearance for basic insulation		T test finger (clause 12 of IEC 60529)
B basic insulation for circuit A	L_2 clearance for reinforced insulation		Z supplementary insulation for circuit A
Bc basic insulation for circuit C	M conductive part		Zc supplementary insulation for circuit C
C adjacent circuit	R reinforced insulation for circuit A		* also applies to plastic screws
D double insulation for circuit A	Rc reinforced insulation for circuit C		† no direct contact
I insulation less than B	S surface of equipment		
NOTE In column c a plastic screw is treated like a metal screw because a user could replace it with a metal screw during the life of the equipment.			

Figure 5 – Examples for protection against direct contact

4.2.3.3 Protection by means of enclosures and barriers

Live parts shall be arranged in enclosures or located behind enclosures or barriers, which meet at least the requirements of the Protective Type IP2X according to 5.1 of IEC 60529. The top surfaces of enclosures or barriers which are accessible when the equipment is energized shall meet at least the requirements of the Protective Type IP3X with regard to vertical access only. See 5.2.2.3 for test.

Where openings which reduce the protection to less than IP1X occur during replacement of certain parts:

- a) suitable precautions shall be taken to avoid unintentional contact, and
- b) it shall be ensured that persons are aware that live parts can be touched.

Open type sub-assemblies and devices, intended for inclusion within a larger device or enclosures which provide the required protection, do not, in themselves, require a protective measure against direct contact. However, components intended for manual operation and other components accessible during such operation shall be protected to IP2X.

Products of decisive voltage classes A, B or C which are intended for installation in closed electrical operating areas, as defined in 3.2.3, need not have protective measures against direct contact. However, a barrier can be required due to other reasons, such as mechanical protection or protection against the deposition of extraneous particles.

Products of decisive voltage class D intended for installation within a closed electrical operating area have additional requirements (see 4.2.13).

4.2.4 Protection in case of direct contact

4.2.4.1 General

Protection in case of direct contact is required to ensure that contact with live parts does not produce a shock hazard.

The protection against direct contact according to 4.2.3 may be waived if the circuit contacted complies with one of the measures given in 4.2.4.2 to 4.2.4.4 provided that protective separation from all other circuits is ensured. See Annex A for examples of these measures.

NOTE The requirements of these subclauses apply to the entire circuit including power supplies and any associated peripheral devices.

Compliance with protective separation requirements shall be verified according to 5.2.1, 5.2.2, and 5.2.3 as appropriate.

4.2.4.2 Protection by means of ELV

Unearthed circuits of decisive voltage class A, and earthed circuits of decisive voltage class A used within a zone of equipotential bonding, do not require protection in case of direct contact.

Earthed circuits of decisive voltage class A that are not within a zone of equipotential bonding require further protection in case of direct contact, by one of the measures given in 4.2.4.3 or 4.2.4.4. The instruction manual shall make mention of this (see 6.3.6.5).

4.2.4.3 Protection by means of protective impedance

The connection of accessible live parts to circuits of decisive voltage class B, C or D shall only be made through protective impedances.

The same constructional provisions as those for protective separation shall be applied for the construction and arrangement of a protective impedance. The current value stated below shall not be exceeded in the event of failure of a single component. When capacitors are connected to the protective impedance, the stored charge available between simultaneously accessible parts shall not exceed 50 μC .

The protective impedances shall be designed so that the current available through them at the accessible live part does not exceed a value of 3,5 mA a.c. or 10 mA d.c. See 5.2.3.4 for test.

The protective impedances shall withstand the impulse voltages and temporary overvoltages for the circuits to which they are connected. See 5.2.3.1 and 5.2.3.2 for tests.

4.2.4.4 Protection by means of limited voltages

This type of protection implies a voltage division technique from a circuit protected against direct contact yielding a voltage to earth not greater than that of decisive voltage class A.

This circuit shall be designed so that, even in the event of failure of a single component in the voltage division circuit, the voltage across output terminals as well as the voltage to earth will not become greater than that of decisive voltage class A. The same constructional measures as in protective separation shall be employed in this case.

This type of protection shall not be used in case of protective class II, because it relies on protective earth being connected.

4.2.5 Protection against indirect contact

4.2.5.1 General

Protection against indirect contact is required to prevent shock currents which can result from exposed conductive parts during an insulation failure. This protection shall comply with the requirements for protective class I, class II or class III.

That part of a PDS which meets the requirements of 4.2.5.2, 4.2.5.3 and 4.2.5.4 is defined as protective class I.

That part of a PDS which meets the requirements of 4.2.5.5 is defined as protective class II.

That part of a PDS which meets the requirements of SELV is defined as protective class III.

Protective class 0 is only acceptable for parts of the PDS when instructions are provided to meet the requirements of 4.2.3.3 (closed electrical operating areas) (see 6.3.6.5). In the case of high-voltage product, special requirements exist (see 4.2.13).

4.2.5.2 Insulation between live parts and exposed conductive parts

Exposed conductive parts of equipment shall be separated from live parts at least by basic insulation or by clearances as in 4.2.6.6.

4.2.5.3 Protective bonding circuit

Other than in a), b), or c) below, protective bonding shall be provided between exposed conductive parts of equipment and the means of connection for the protective conductor:

- a) when exposed conductive parts are only related to SELV or PELV circuits as described in 4.2.4.2;
- b) when exposed conductive parts are only related to circuits of limited voltage as described in 4.2.4.4;
- c) when exposed conductive parts are separated from live parts using double or reinforced insulation.

Where electrical equipment is mounted on lids, doors, or cover plates, continuity of the protective bonding circuit shall be ensured and it is recommended that a protective conductor be used. Otherwise fastenings, hinges or sliding contacts designed to have a low resistance shall be used.

Protective bonding conductors shall comply with 4.2.5.4.

Metal ducts of flexible or rigid construction and metallic sheaths shall not be used as protective conductors. For high-voltage products, metal ducts and metal sheathing of all connecting cables (e.g. cable armouring, lead sheath) shall be connected to the protective bonding circuit. If only one end of such ducting or sheathing is so connected, it shall not be possible to touch the other end. This shall be connected to the protective bonding circuit via an impedance to limit any induced voltage to a maximum of 50 V a.c.

The electrical resistance from any exposed conductive part to the means of connection of the protective bonding conductor shall not exceed 0,1 Ω . See 5.2.3.10 for test.

For low-voltage products, a protective conductor shall be connected at all times when power is supplied to the PDS. If routed through a plug and socket, or similar means of disconnection, it shall not be possible to interrupt the protective conductor unless power is simultaneously removed from the part to be protected.

For high-voltage products, the protective bonding circuit shall not incorporate a switching device, an overcurrent device (e.g. switch, fuse) or means of current detection for such devices.

4.2.5.4 Means of connection for the protective conductor

4.2.5.4.1 General

Every PDS or PDS element (motor, converter, transformer) requiring protective bonding shall have a means of connection for the external protective conductor, located near the terminals for the respective live conductors. The means of connection shall be corrosion-resistant and shall be suitable for the connection of cables according to Table 2 and of cables in accordance with the wiring rules applicable at the installation. The means of connection for the external protective conductor shall not be used as a part of the mechanical assembly of the equipment or for other connections. A separate means of connection shall be provided for each external protective conductor.

For special system topologies, such as 6-phase motors, the PDS designer shall verify the protective conductor cross-section required.

For high-voltage products, the high voltage cables shall have provision for protective bonding in accordance with IEC 60204-11 and IEC 61800-4. The protective bonding concept shall be by agreement between the supplier and user and consistent with local requirements in the area of installation.

Connection and bonding points shall be so designed that their current-carrying capacity is not impaired by mechanical, chemical, or electrochemical influences. Where enclosures and/or conductors of aluminium or aluminium alloys are used, particular attention should be given to the problems of electrolytic corrosion.

Table 2 – Protective conductor cross-section

Cross-sectional area of phase conductors of the installation S mm^2	Minimum cross-sectional area of the corresponding protective conductor S_p mm^2
$S \leq 16$	S
$16 < S \leq 35$	16
$35 < S$	$S/2$

The values in Table 2 are valid only if the protective conductor is made of the same metal as the phase conductors. If this is not so, the cross-sectional area of the protective conductor is to be determined in a manner which produces a conductance equivalent to that which results from the application of Table 2.

The cross-sectional area of every protective conductor which does not form part of the supply cable or cable enclosure shall be, in any case, not less than:

- 2,5 mm² if mechanical protection is provided;
- 4 mm² if mechanical protection is not provided. For cord-connected equipment, provisions shall be made so that the protective conductor in the cord shall, in the case of failure of the strain-relief mechanism, be the last conductor to be interrupted.

See 6.3.6.7 for marking requirements.

4.2.5.4.2 Connection under high leakage current

If the leakage current (measured in accordance with 5.2.3.5) is higher than 3,5 mA a.c. or 10 mA d.c., a fixed connection is required and one or more of the following conditions shall be satisfied:

- a cross-section of the protective conductor of at least 10 mm² Cu or 16 mm² Al;
- automatic disconnection of the supply in case of discontinuity of the protective conductor;
- provision of an additional terminal for a protective conductor of the same cross-sectional area as the original protective conductor.

In addition, the caution symbol B.3.1 of ISO 3864 shall be fixed to the product and information inserted in the installation manual (see 6.3.6.8 and Annex B).

In PDS designed for fixed installation, where the cross-sectional area of the protective conductor determined from Table 2 is greater than 10 mm² Cu (or 16 mm² Al), the leakage current need not be measured.

4.2.5.5 Special features in equipment for protective class II

If equipment is designed to use double or reinforced insulation between live parts and accessible surfaces in accordance with 4.2.3.2, then the design is considered to meet protective class II, if the following also apply:

- equipment designed to protective class II shall not have means of connection for the protective conductor. However this does not apply if the protective conductor is passed through the equipment to equipment series-connected beyond it. In the latter event, the protective conductor and its means for connection shall be insulated with basic insulation from the accessible surface of the equipment and from circuits which employ protective separation, extra-low voltage, protective impedance and limited discharging energy, according to 4.2.4. This basic insulation shall correspond to the rated voltage of the series-connected equipment;
- metal-encased equipment of protective class II may have provision on its enclosure for the connection of an equipotential bonding conductor;
- equipment of protective class II may have provision for the connection of an earthing conductor for functional reasons or for the damping of overvoltages; it shall, however, be insulated as though it is a live part;
- equipment of protective class II shall be classified on the name plate with symbol 5172 of IEC 60417.

4.2.6 Insulation

4.2.6.1 General

This subclause gives minimum requirements for insulation, based on the principles of IEC 60664 and IEC 60071.

Manufacturing tolerances shall be taken into account during design and installation of the PDS.

4.2.6.2 Factors affecting insulation

4.2.6.2.1 General

Insulation shall be selected after consideration of the following influences:

- pollution degree;
- overvoltage category;
- system voltage;
- working voltage;
- type of insulation;
- location of insulation;
- type of circuit considered;
- altitude.

Verification of insulation shall be made according to 5.2.2.1, 5.2.3.1, 5.2.3.2, and 5.2.3.3.

4.2.6.2.2 Pollution degree

Insulation, especially when provided by clearances and creepage distances, is affected by pollution which occurs during the service life of the PDS. The micro-environmental conditions for insulation shall be applied according to Table 3.

Table 3 – Definitions of pollution degrees

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

In accordance with IEC 61800-1, IEC 61800-2 and IEC 61800-4, a standard PDS is designed for pollution degree 2. This requires that one of the following apply:

- a) instructions are provided with the PDS indicating that it shall be installed in a pollution degree 2 environment; or
- b) the specific installation application of the PDS is known to be a pollution degree 2 environment; or
- c) the PDS enclosure provides adequate protection against what is expected in pollution degree 3 and 4 (conductive pollution and condensation)

If none of these requirements are met, pollution degree 3 shall be assumed in determining the insulation. Thereby the PDS is usable for pollution degree 1, 2 and 3 environments. If operation in pollution degree 4 is required, item c) shall be met.

4.2.6.2.3 Overvoltage category

The concept of overvoltage categories (based on IEC 60664-1) is used for equipment energized from the supply mains. Four categories are considered:

- category IV applies to equipment used at the origin of an installation. Examples are electricity meters and primary overcurrent protection equipment;
- category III applies to equipment in fixed installations. Examples are switchgear and equipment for permanent connection to an industrial installation;
- category II applies to equipment powered from the fixed installation. Examples are appliances, portable tools and household equipment;
- category I applies to equipment connected to a circuit where measures have been taken to reduce transient overvoltages to a low level.

4.2.6.2.4 Supply earthing systems

Three basic types of earthing system are described in IEC 60364-1. They are:

- **TN system:** has one point directly earthed, the exposed conductive parts of the installation being connected to that point by protective conductors. Three types of TN system, TN-C, TN-S and TN-C-S, are defined according to the arrangement of the neutral and protective conductors;
- **TT system:** has one point directly earthed, the exposed conductive parts of the installation being connected to earth electrodes electrically independent of the earth electrodes of the power system;
- **IT system:** has all live parts isolated from earth or one point connected to earth through an impedance, the exposed conductive parts of the installation being earthed independently or collectively to the earthing system.

4.2.6.3 Insulation to the surroundings**4.2.6.3.1 General**

Insulation for basic, supplementary, and reinforced insulation between a circuit and its surroundings, shall be designed according to:

- the impulse voltage; or
- the temporary overvoltage; or
- the working voltage of the circuit.

For creepage distances, the r.m.s. value of the working voltage is used: for clearance distances and solid insulation, the recurring peak value is used, as described in 4.2.6.3.2 to 4.2.6.3.4.

NOTE Examples of working voltage with the combination of a.c., d.c. and recurring peaks are on the d.c. link of an indirect voltage source converter, or the damped oscillation of a thyristor snubber, or internal voltages of a switch-mode power supply.

The impulse voltage and temporary overvoltage depend on the system voltage of the circuit, and the impulse voltage also depends on the overvoltage category, as shown in Table 4 (for low-voltage PDS) and Table 5 (for high-voltage PDS).

The system voltage in column 1 of these tables is:

- For Table 4
 - in TN and TT systems: the r.m.s. value of the rated voltage between a phase and earth;

NOTE A corner-earthed system is a TN system with one phase earthed, in which the system voltage is the r.m.s. value of the rated voltage between a non-earthed phase and earth.

 - in three-phase IT systems:
 - for determination of impulse voltage, the r.m.s. value of the rated voltage between a phase and an artificial neutral point (an imaginary junction of equal impedances from each phase);
 - for determination of temporary overvoltage, the r.m.s. value of the rated voltage between phases;
 - in single-phase IT systems: the r.m.s. value of the rated voltage between phases.
- For Table 5: the r.m.s. value of the rated voltage between phases.

4.2.6.3.2 Circuits connected directly to the supply mains

Insulation between the surroundings and circuits which are connected directly to the supply mains shall be designed according to the impulse voltage, temporary overvoltage, or recurring peak value of the working voltage, whichever gives the most severe requirement.

This insulation is normally evaluated to withstand impulses of overvoltage category III, except that overvoltage category IV shall be used when the PDS is connected directly to the origin of the installation. Overvoltage category II may be used for plug-in equipment connected to a supply for non-industrial purposes without special requirements with regard to reliability.

If measures are provided which reduce transient overvoltages of category IV to values of category III, or values of category III to values of category II, basic or supplementary insulation may be designed for the reduced values. Devices used for such measures shall be approved by a suitable safety authority for use at the maximum intended supply voltage (including tolerances). Where appropriate, the measures shall be monitored.

The requirements for double or reinforced insulation shall not be reduced.

NOTE 1 Circuits which are connected to the supply mains via protective impedances, according to 4.2.4.3, or via means of voltage limitation, according to 4.2.4.4, are not regarded as connected directly to the supply mains.

NOTE 2 A high-voltage PDS generally includes a dedicated transformer. The primary of the transformer is fed from the supply mains, and the transformer complies with its own product standard. The requirements of this part of IEC 61800 apply to the circuits fed by the secondary of the transformer.

4.2.6.3.3 Circuits not connected directly to the supply mains

Insulation between the surroundings and circuits not connected directly (that is, having no galvanic connection) to the supply mains shall be designed according to the impulse voltage or the working voltage, whichever gives the more severe requirement. This insulation is evaluated to withstand impulses of overvoltage category II.

If measures are provided which reduce transient overvoltages of category III to values of category II, or values of category II to values of category I, basic or supplementary insulation may be designed for the reduced value. Devices used for such measures shall be approved by a suitable safety authority for use at the maximum intended supply voltage (including tolerances). Where appropriate, the measures shall be monitored.

The requirements for double or reinforced insulation shall not be reduced.

4.2.6.3.4 Insulation between circuits

Insulation between two circuits shall be designed according to the circuit having the more severe requirement.

4.2.6.4 Insulation within a circuit

Functional insulation within a circuit shall be designed according to the working voltage of the circuit.

In addition, insulation within a circuit connected directly to the supply mains shall be designed according to the impulse voltage of overvoltage category II, for a low voltage circuit, or category III, for a high voltage circuit. Where measures are provided which reduce transient overvoltages of category III to values of category II, or values of category II to values of category I, functional insulation may be designed for the reduced values.