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GROUP SAFETY PUBLICATION
PUBLICATION GROUPEE DE SÉCURITÉ

Safety requirements for power electronic converter systems and equipment – Part 1: General

**Exigences de sécurité applicables aux systèmes et matériels électroniques
de conversion de puissance –
Partie 1: Généralités**



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Exigences de sécurité applicables aux systèmes et matériels électroniques de conversion de puissance – Partie 1: Généralités

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SAFETY REQUIREMENTS FOR POWER ELECTRONIC CONVERTER SYSTEMS AND EQUIPMENT –

Part 1: General

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It has the status of a group safety publication in accordance with IEC Guide 104.

The text of this standard is based on the following documents:

FDIS	Report on voting
22/200/FDIS	22/204/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all the parts in the IEC 62477 series, published under the general title *Safety requirements for power electronic convertor systems and equipment* can be found on the IEC website.

In this standard, terms in *italic* are defined in Clause 3.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

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INTRODUCTION

This International Standard relates to products that include power electronic converters, with a rated system voltage not exceeding 1 000 V a.c. or 1 500 V d.c. It specifies requirements to reduce risks of fire, electric shock, thermal, energy and mechanical hazards, except functional safety as defined in IEC 61508. The objectives of this document are to establish a common terminology and basis for the safety requirements of products that contain power electronic converters across several IEC technical committees.

This standard has been developed with the intention:

- to be used as a reference document for product committees inside TC 22 in the development of product standards for power electronic converter systems and equipment;
- to replace IEC 62103 as a product family standard providing minimum requirements for safety aspects of power electronic converter systems and equipment in apparatus for which no product standard exists; and

NOTE The scope of IEC 62103 contains reliability aspects, which are not covered by this standard.

- to be used as a reference document for product committees outside TC 22 in the development of product standards of power electronic converter systems and equipment intended renewable energy sources. TC 82, TC 88, TC 105 and TC 114, in particular, have been identified as relevant technical committees at the time of publication.

Technical committees using this document should carefully consider the relevance of each paragraph in this document for the product under consideration and reference, add, replace or modify requirement as relevant. Product specific topics not covered by this document are in the responsibility of the technical committees using this document as reference document.

This group safety standard will not take precedence on any product specific standard according to IEC Guide 104. IEC Guide 104 provides information about the responsibility of product committees to use group safety standards for the development of their own product standards.

SAFETY REQUIREMENTS FOR POWER ELECTRONIC CONVERTER SYSTEMS AND EQUIPMENT –

Part 1: General

1 Scope

This part of IEC 62477 applies to Power Electronic Converter Systems (PECS) and equipment, their components for *electronic power conversion* and electronic power switching, including the means for their control, protection, monitoring and measurement, such as with the main purpose of converting electric power, with rated system voltages not exceeding 1 000 V a.c. or 1 500 V d.c.

This document may also be used as a reference standard for product committees producing product standards for:

- adjustable speed electric power drive systems (PDS);
- standalone uninterruptible power systems (UPS);
- low voltage stabilized d.c. power supplies.

For PECS for which no product standard exists, this standard provides minimum requirements for safety aspects.

This part of IEC 62477 has the status of a group safety publication in accordance with IEC Guide 104 for power electronic converter systems and equipment for solar, wind, tidal, wave, fuel cell or similar energy sources.

According to IEC Guide 104, one of the responsibilities of technical committees is, wherever applicable, to make use of basic safety publications and/or group safety publications in the preparation of their product standards.

This International Standard:

- establishes a common terminology for safety aspects relating to PECS and equipment;
- establishes minimum requirements for the coordination of safety aspects of interrelated parts within a PECS;
- establishes a common basis for minimum safety requirements for the PEC portion of products that contain PEC;
- specifies requirements to reduce risks of fire, electric shock, thermal, energy and mechanical hazards, during use and operation and, where specifically stated, during service and maintenance;
- specifies minimum requirements to reduce risks with respect to pluggable and permanently connected equipment, whether it consists of a system of interconnected units or independent units, subject to installing, operating and maintaining the equipment in the manner prescribed by the manufacturer.

This International Standard does not cover:

- telecommunications apparatus other than power supplies to such apparatus;
- functional safety aspects as covered by e.g. IEC 61508;
- electrical equipment and systems for railways applications and electric vehicles.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050 (all parts), *International Electrotechnical Vocabulary* (available at <<http://www.electropedia.org>>)

IEC 60060-1:2010, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60068-2-2, *Environmental testing – Part 2-2: Tests – Test B: Dry heat*

IEC 60068-2-6, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-52, *Environmental testing – Part 2-52: Tests – Test Kb: Salt mist, cyclic (sodium chloride solution)*

IEC 60068-2-68, *Environmental testing – Part 2-68: Tests – Test L: Dust and sand*

IEC 60068-2-78:2001, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60112:2003, *Method for the determination of the proof and the comparative tracking indices of solid insulating materials*

IEC 60216-4-1, *Electrical insulating materials – Thermal endurance properties – Part 4-1: Ageing ovens – Single-chamber ovens*

IEC 60364-1, *Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions*

IEC 60364-4-41:2005, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*

IEC 60364-4-44:2007, *Low-voltage electrical installations – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances*

IEC 60364-5-54:2011, *Low voltage electrical installations – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements and protective conductors*

IEC 60417, *Graphical symbols for use on equipment* (available at <<http://www.graphical-symbols.info/equipment>>)

IEC/TS 60479-1, *Effects of current on human beings and livestock – Part 1: General aspects*

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

IEC 60617, *Graphical symbols for diagrams* (available from <<http://std.iec.ch/iec60617>>)

IEC 60664-1:2007, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60664-3:2003, *Insulation coordination for equipment within low-voltage systems – Part 3: Use of coating, potting or moulding for protection against pollution*

IEC 60664-4:2005, *Insulation coordination for equipment within low-voltage systems – Part 4: Consideration of high-frequency voltage stress*

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 60695-10-2, *Fire hazard testing – Part 10-2: Abnormal heat - Ball pressure test*

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

IEC 60721-3-3, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 3: Stationary use at weatherprotected locations*

IEC 60721-3-4, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 4: Stationary use at non-weatherprotected locations*

IEC 60730-1, *Automatic electrical controls for household and similar use – Part 1: General requirements*

IEC/TR 60755, *General requirements for residual current operated protective devices*

IEC 60949, *Calculation of thermally permissible short-circuit currents, taking into account non-adiabatic heating effects*

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

IEC 60695-2-13, *Fire hazard testing – Part 2-13: Glowing/hot-wire based test methods – Glow-wire ignition temperature (GWIT) test method for materials*

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

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

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

IEC 61032:1997, *Protection of persons and equipment by enclosures – Probes for verification*

IEC 61180-1:1992, *High-voltage test techniques for low-voltage equipment – Part 1: Definitions, test and procedure requirements*

IEC Guide 104:2010, *The preparation of safety publications and the use of basic safety publications and group safety publications*

IEC Guide 117:2010, *Electrotechnical equipment – Temperatures of touchable hot surfaces*

ISO 3864-1, *Graphical symbols – Safety colours and safety signs – Part 1: Design principles for safety signs in workplaces and public areas*

ISO 3746, *Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – Survey method using an enveloping measurement surface over a reflecting plane*

ISO 7000, *Graphical symbols for use on equipment – Index and synopsis* (available from <<http://www.graphical-symbols.info/equipment>>)

ISO 7010, *Graphical symbols – Safety colours and safety signs – Registered safety signs*

ISO 9614-1, *Acoustics – Determination of sound power levels of noise sources using sound intensity – Part 1: Measurement at discrete points*

ISO 9772, *Cellular plastics – Determination of horizontal burning characteristics of small specimens subjected to a small flame*

ANSI/ASTM E84 – 11b, *Standard test method for surface burning characteristics of building materials*

ASTM E162 – 11a, *Standard test method for surface flammability of materials using a radiant heat energy source*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-111:1996, IEC 60050-151:2001, IEC 60050-161:1990, IEC 60050-191:1990, IEC 60050-441:1984, IEC 60050-442:1998, IEC 60050-551:1998, IEC 60050-601:1985 and IEC 60664-1:2007, and the following apply.

Table 1 provides an alphabetical cross-reference listing of terms.

Table 1 – Alphabetical list of terms

Term	Term number	Term	Term number	Term	Term number
adjacent circuit	3.1	low voltage	3.23	protective separation	3.44
basic insulation	3.2	mains supply	3.24	PEC	3.45
basic protection	3.3	muscular reaction (inability to let go)	3.25	PECS	3.46
commissioning test	3.4	non-mains supply	3.26	reinforced insulation	3.47
decisive voltage class (DVC)	3.5	open type	3.27	restricted access area	3.48
double insulation	3.6	output short circuit current	3.28	routine test	3.49
DVC As	3.7	PELV (systems)	3.29	sample test	3.50
DVC Ax	3.8	permanently connected (equipment)	3.30	SELV (systems)	3.51
electrical breakdown	3.9	pluggable equipment type A	3.31	short circuit backup protection	3.52
(electrical) insulation	3.10	pluggable equipment type B	3.32	simple separation	3.53
(electronic) (power) conversion	3.11	port	3.33	single fault condition	3.54
enclosure	3.12	power semiconductor device	3.34	startle reaction	3.55
enhanced protection	3.13	prospective short circuit current	3.35	supplementary insulation	3.56
expected lifetime	3.14	protective equipotential bonding	3.36	surge protective device (SPD)	3.57
Extra Low Voltage (ELV)	3.15	protective class I	3.37	system	3.58
fault protection	3.16	protective class II	3.38	system voltage	3.59
field wiring terminal	3.17	protective class III	3.39	temporary overvoltage	3.60
fire enclosure	3.18	protective earthing (PE)	3.40	touch current	3.61
functional insulation	3.19	PE conductor	3.41	type test	3.62
hazardous live part	3.20	protective impedance	3.42	ventricular fibrillation	3.63
installation	3.21	(electrically) protective screening	3.43	working voltage	3.64
live part	3.22			zone of equipotential bonding	3.65

3.1**adjacent circuit**

circuit next to the circuit under consideration having a requirement for functional, simple or protective *insulation*

3.2**basic insulation**

insulation applied to *hazardous live parts* to provide *basic protection* against electric shock

[SOURCE: IEC 60050-195:1998, 195-06-06, modified]

3.3**basic protection**

protection against electric shock under fault-free conditions

[SOURCE: IEC 60050-195:1998, 195-06-01]

3.4

commissioning test

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

[SOURCE: IEC 60050-411:1996, 411-53-06, modified]

3.5

decisive voltage class

DVC

classification of voltage range used to determine the protective measures against electric shock and the requirements of *insulation* between circuits

3.6

double insulation

insulation comprising both *basic insulation* and *supplementary insulation*

[SOURCE: IEC 60050-826:2004, 826-12-16]

3.7

DVC As

maximum safe voltage values to be touchable, coming from *DVC Ax*

3.8

DVC Ax

DVC Ax is the general *DVC* value used for *DVC A*, *DVC A1*, *DVC A2* or *DVC A3*

3.9

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

[SOURCE: IEC 60664-1:2007, 3.20]

3.10

(electrical) insulation

electrical separation between circuits or conductive parts provided by clearance or creepage distance or solid *insulation* or combinations of them

3.11

(electronic) (power) conversion

change of one or more of the characteristics of an electric power *system* essentially without appreciable loss of power by means of *power semiconductor devices*

Note 1 to entry: Characteristics are, for example, voltage, number of phases and frequency, including zero frequency.

[SOURCE: IEC 60050-551:1998, 551-11-02, modified]

3.12**enclosure**

housing affording the type and degree of protection suitable for the intended application

Note 1 to entry: This standard provides requirement for the *enclosure* according to IEC 60529 as well as additional requirement for mechanical and environmental impact. The purpose of the additional requirement is to ensure the *enclosures* ability to provide *basic protection* under the environmental conditions specified by the manufacturer.

[SOURCE: IEC 60050-195:1998, 195-02-35]

3.13**enhanced protection**

protective provision having a reliability of protection not less than that provided by two independent protective provisions

3.14**expected lifetime**

design duration for which the performance characteristics are valid at rated conditions of operation

3.15**extra-low voltage****ELV**

voltage not exceeding the relevant voltage limit of band I specified in IEC 60449

Note 1 to entry: In IEC 60449, band I is defined as not exceeding 50 V a.c. r.m.s. and 120 V d.c. Other product committees may have defined *ELV* with different voltage levels.

Note 2 to entry: In this standard, protection against electric shock is dependent on the *decisive voltage classification*.

[SOURCE: IEC 60050-826:2004, 826-12-30, modified]

3.16**fault protection**

protection against electric shock under single-fault conditions

Note 1 to entry: For low-voltage *installations, systems* and equipment, *fault protection* generally corresponds to protection against indirect contact as used in IEC 60364-4-41, mainly with regard to failure of *basic insulation*.

[SOURCE: IEC 60050-195:1998, Amendment 1:1998, 195-06-02]

3.17**field wiring terminal**

terminal provided for connection of external conductors to the *PECS*

3.18**fire enclosure**

part of the equipment intended to minimize the spread of fire or flames from within

3.19**functional insulation**

insulation between conductive parts within a circuit that is necessary for the proper functioning of the circuit, but which does not provide protection against electric shock

Note 1 to entry: *Functional insulation* may, however, reduce the likelihood of ignition and fire.

3.20

hazardous-live-part

live part which, under certain conditions, can give a harmful electric shock

[SOURCE: IEC 60050-195:1998, 195-06-05]

3.21

installation

equipment or equipments including at least the PECS

Note 1 to entry: The word installation is also used in this standard to denote the process of installing a *PECS*. In these cases, the word does not appear in italics.

3.22

live part

conductor or conductive part intended to be energized in normal operation, including a neutral conductor, but by convention not a *protective earth conductor* or *protective earth* neutral

Note 1 to entry: This concept does not necessarily imply a risk of electric shock.

[SOURCE: IEC 60050-195:1998, 195-02-19, modified]

3.23

low voltage

LV

set of voltage levels used for the distribution of electricity and whose upper limit is generally accepted to be 1 000 V a.c. or 1 500 V d.c.

[SOURCE: IEC 60050-601:1985, 601-01-26, modified]

3.24

mains supply

low voltage a.c. power distribution *system* for supplying power to a.c. equipment

3.25

muscular reaction (inability to let go)

physiological reaction due to a minimum derived value of touch voltage for a population for which a current flowing through the body is just enough to cause involuntary contraction of a muscle, such as inability to let go from an electrode, but not including *startle reaction*

[SOURCE: IEC/TR 60479-5:2007, 3.3.2, modified]

3.26

non-mains supply

electrical circuit that is not energized directly from the *mains supply*, but is, for example, isolated by a transformer or supplied by a battery, generator, or similar sources not directly connected to the a.c. power distribution *system*

3.27

open type

product intended for incorporation within *enclosure* or assembly that will provide protection against hazards

3.28

output short circuit current

available current r.m.s. or d.c. that flows at the output of the *PECS* when a short circuit is applied by a conductor of negligible impedance

3.29**PELV (system)**

electric system in which the voltage cannot exceed the value of *extra low voltage*:

- under normal conditions; and
- under *single fault conditions*, except earth faults in other electric circuits

Note 1 to entry: PELV is the abbreviation for protective *extra low voltage*.

[SOURCE: IEC 60050-826:2004, 826-12-32]

3.30**permanently connected (equipment)**

equipment that is intended for connection to the building *installation* wiring using screw terminals or other reliable means

3.31**pluggable equipment type A**

equipment that is intended for connection to the *mains supply* via a non-industrial plug and socket-outlet or a non-industrial appliance coupler, or both

3.32**pluggable equipment type B**

equipment that is intended for connection to the *mains supply* via an industrial plug and socket-outlet or an appliance coupler, or both, complying with IEC 60309 or with a comparable national standard

3.33**port**

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

[SOURCE: IEC 60050-131:2002, 131-12-60]

3.34**power semiconductor device**

semiconductor device used for *electronic power conversion*

3.35**prospective short circuit current**

available current that flows when a short circuit is applied by a conductor of negligible impedance

3.36**protective-equipotential-bonding**

equipotential bonding for purposes of safety (e.g. protection against electric shock)

[SOURCE: IEC 60050-195:1998, 195-01-15, modified]

3.37**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*

3.38

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 *supplementary insulation* or *reinforced insulation* are provided, there being no provision for *protective earthing* or reliance upon *installation conditions*

3.39

protective class III

equipment in which protection against electric shock relies on supply at *DVC Ax* (or *B* under certain conditions) and in which voltages higher than those of *DVC Ax (B)* are not generated and there is no provision for *protective earthing*

Note 1 to entry: Other standards define *protective class III* as supplied by *ELV*.

3.40

protective earthing

PE

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

3.41

PE conductor

conductor in the building *installation* wiring, or in the power supply cord, connecting a main *protective earthing* terminal in the equipment to an earth point in the building *installation* for safety purposes

3.42

protective impedance

impedance connected between *hazardous live parts* and accessible 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 ability is maintained throughout the life of the equipment

[SOURCE: IEC 60050-442:1998, 442-04-24, modified]

3.43

(electrically) protective screening

separation of circuits from hazardous live-parts by means of an interposed conductive screen, connected to the means of connection for a *PE conductor*, either directly or via *protective equipotential bonding*

3.44

(electrically) protective separation

separation of one electric circuit from another by means of:

- *double insulation* or
- *basic insulation* and electrically *protective screening* or
- *reinforced insulation*

[SOURCE: IEC 60050-195:1998, Amendment 1:1998, 195-06-19]

3.45

power electronic converter

PEC

device or part thereof for the purpose of *electronic power conversion*, including signalling, measurement, control circuitries and other parts, if essential for the *power conversion* function

3.46**power electronic converter system****PECS**

one or more *power electronic converters* intended to work together with other equipment

3.47**reinforced insulation**

insulation of hazardous-live-parts which provides a degree of protection against electric shock equivalent to *double insulation*

[SOURCE: IEC 60664-1:2007, 3.17.5]

3.48**restricted access area**

area accessible only to electrically skilled persons and electrically instructed persons with the proper authorization

Note 1 to entry: An electrically skilled person is a person with relevant education and experience to enable him or her to perceive risks and to avoid hazards which electricity can create

Note 2 to entry: An electrically instructed person is a person adequately advised or supervised by electrically skilled persons to enable him or her to perceive risks and to avoid hazards which electricity can create

[SOURCE: IEC 60050-195:1998, 195-04-04, modified]

3.49**routine test**

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

[SOURCE: IEC 60050-411:1996, 411-53-02, modified]

3.50**sample test**

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

3.51**SELV (system)**

electric system in which the voltage cannot exceed the value of *extra-low voltage*:

- under normal conditions; and
- under *single fault conditions*, including earth faults in other electric circuits

NOTE SELV is the abbreviation for safety *extra low voltage*.

[SOURCE: IEC 60050-826:2004, 826-12-31, modified]

3.52**short circuit backup protection**

protection that is intended to operate when other protective measures within a *system* or equipment fail to clear a fault

3.53**simple separation**

separation between electric circuits or between an electric circuit and local earth by means of *basic insulation*

[SOURCE: IEC 60050-826:2004, 826-12-28]

3.54

single fault condition

condition in which one failure is present which could cause a hazard covered by this standard

Note 1 to entry: If a *single fault condition* results in other subsequent failures, the set of failures is considered as one *single fault condition*.

Note 2 to entry: Examples of hazards include, but are not limited to electric shock, fire, energy, mechanical, sonic pressure etc.

3.55

startle reaction

physiological reaction due to a minimum derived value of touch voltage for a population for which a current flowing through the body is just enough to cause involuntary muscular contraction to the person through which it is flowing

[SOURCE: IEC/TR 60479-5:2007, 3.3.1, modified]

3.56

supplementary insulation

independent *insulation* applied in addition to *basic insulation* for *fault protection*

Note 1 to entry: *Basic* and *supplementary insulation* are separate, each designed for *simple separation* against electric shock.

[SOURCE: IEC 60664-1: 2007, 3.17.3, modified]

3.57

surge protective device

SPD

device that contains at least one non-linear component that is intended to limit surge voltages and divert surge currents

Note 1 to entry: An SPD is a complete assembly, having appropriate connecting means.

[SOURCE: IEC 61643-11:2011, 3.1.1]

3.58

system

set of interrelated and/or interconnected independent elements

Note 1 to entry: A *system* is generally defined with the view of achieving a given objective, for example by performing a definite function.

3.59

system voltage

voltage used to determine *insulation* requirements

Note 1 to entry: See 4.4.7.1.6 for further consideration of *system voltage*.

3.60

temporary overvoltage

overvoltage at power frequency of relatively long duration

[SOURCE: IEC 60664-1:2007, 3.7.1]

3.61

touch current

electric current passing through a human body or through an animal body when it touches one or more accessible parts of an electrical *installation* or electrical equipment

[SOURCE: IEC 60050-826:2004, 826-11-12]

3.62**type test**

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

[SOURCE: IEC 60050-811:1991, 811-10-04]

3.63**ventricular fibrillation**

cardiac fibrillation, limited to the ventricles, leading to ineffective circulation and then to heart failure

Note 1 to entry: Ventricular fibrillation stops blood circulation.

[SOURCE: IEC 60050-891:1998, 891-01-16]

3.64**working voltage**

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

Note 1 to entry: The *working voltage* can be d.c. or a.c. Both the r.m.s. and recurring peak values are used.

3.65**zone of equipotential bonding**

zone where all simultaneously accessible conductive parts are electrically connected to prevent hazardous voltages appearing between them

Note 1 to entry: For equipotential bonding, it is not necessary for the parts to be earthed.

4 Protection against hazards**4.1 General**

Clause 4 defines the minimum requirements for the design and construction of a *PECS*, to ensure its safety during installation, normal operating conditions and maintenance for the *expected lifetime* of the *PECS*. Consideration is also given to minimising hazards resulting from reasonably foreseeable misuse.

Manufacturers and product committees using this standard as a reference document shall clearly specify what is contained in the *PECS*, covered by and evaluated according to this standard. This shall as a minimum cover the *PEC* including the load interface and supply interface.

Protection against hazards shall be maintained under normal and *single fault conditions*, as specified in this standard.

Components compliant with a relevant IEC product standard which provides similar safety requirements as the requirement of this standard do not require separate evaluation. Components or assemblies of components, for which no relevant product standard exists, shall be tested according to the requirements of this standard.

Product committees using this standard as reference should make use of 7.3 from IEC Guide 104:2010.

Where the *PECS* is intended to be used together with specific auxiliary equipment, the safety evaluation and test shall include this auxiliary equipment unless it can be shown that it does not affect the safety of either equipment.

4.2 Fault and abnormal conditions

The *PECS* shall be designed to avoid operating modes or sequences that can cause a fault condition or component failure leading to a hazard, unless other measures to prevent the hazard are provided by the *installation* and are described in the installation information provided with the *PECS*. The requirements in this clause also apply to abnormal operating conditions as applicable.

Circuit analysis or testing shall be performed to determine whether or not failure of a particular component (including *insulation systems*) would result in hazard.

This analysis shall include situations where a failure of the component or the *insulation (functional, basic and supplementary)* would result in:

- an impact on the decisive voltage determination according to 4.4.2;
- a risk of electric shock due to:
 - degradation of the *basic protection* according to 4.4.3, or
 - degradation of the *fault protection* according to 4.4.4;
- a risk of energy hazard according to 4.5;
- a risk of degradation due to emission of flame, burning particles or molten metal of the fire according to 4.6;
- a risk of thermal hazard due to high temperature according to 4.6;
- a risk of mechanical hazard according to 4.7.

NOTE This standard does not provide any requirement to protect against chemical hazard. Product committees or manufacturers might consider this when it applies to their products.

The analysis or testing shall include the effect of short circuit and open-circuit conditions of the component. Testing is necessary unless analysis can conclusively show that no hazard will result from failure of the component. Compliance shall be checked by test of 5.2.4.6.

The evaluation of components shall be based on the expected stress occurring in the *expected lifetime* of the *PECS* including, but not limited to:

- specified climatic and mechanical conditions according to 4.9 (temperature, humidity, vibration, etc.);
- electrical characteristics according to 4.4.7 (expected impulse voltage, *working voltage*, *temporary overvoltage*, etc.);
- micro environment according to 4.4.7 (pollution degree, humidity, etc.).

Components evaluated for their reliability according to relevant product standards are considered to meet these requirements and do not need any further investigation, if tested under conditions that fulfill the conditions for which the *PECS* is designed.

Clearance and creepage distances on printed wiring boards (PWBs) including components mounted on PWBs, for *functional*, *basic*, *supplementary* and *reinforced insulation*, designed according to 4.4.7.4 and 4.4.7.5, are considered to meet these requirements and do not need any further investigation.

Functional insulation on PWB and between legs of components assembled on PWBs not fulfilling the requirements for clearance and creepage distance in 4.4.7.4 and 4.4.7.5 shall meet the requirement of 4.4.7.7.

Consideration shall be given to potential safety hazards associated with major component parts of the *PECS*, such as flammability of transformer and capacitor fluids.

4.3 Short circuit and overload protection

4.3.1 General

The *PECS* shall not present a hazard, under short circuit or overload conditions at any *port*, including phase to phase, phase to earth and phase to neutral. Adequate information shall be provided in the documentation to allow proper selection of external wiring and protective devices (see 6.3.7.6 and 6.3.7.7).

Protective *systems* or devices shall be provided or specified in sufficient quantity and location so as to detect and to interrupt or limit the current flowing in any possible fault current path between conductors or from conductors to earth.

NOTE 1 In this standard, the term overcurrent covers both short circuit and overload.

NOTE 2 Local *installation* codes will still usually require provision of such protection for the purposes of protecting the input wiring in the *installation*.

Protection against overcurrents shall be provided for all input circuits, and for output circuits that do not comply with the requirements for limited power sources in 4.6.5.

If the *PECS* complies with all normal, abnormal and fault test conditions in this standard without such protection provided, provision or specification of overcurrent protection for input circuits is not necessary for the protection of the *PECS*.

No protection is required against overcurrent to earth in equipment that either

- has no connection to earth; or
- has *double insulation* or *reinforced insulation* between *live parts* and all parts connected to earth.

NOTE 3 Under a *single fault condition* in an IT system no short circuit current or a limited short circuit current will flow. The interruption of the short circuit current in an IT system (see 4.4.7.1.4) is done when a second fault occurs. Typically only detection is done after the first fault in an IT *system*.

NOTE 4 Where *double insulation* or *reinforced insulation* is provided, a short circuit to earth would be considered to be two faults.

For *pluggable equipment type A*, the protective device is provided in the *installation* and shall not require any specific characteristics other than that required in IEC 60364 or other local *installation* codes.

For *pluggable equipment type B* or fixed installed equipment, this protection may be provided by devices external to the equipment, in which case the installation instructions shall state the need for the protection to be provided in the *installation* and shall include the specifications for the required short circuit and/or overload protection (see 6.3.7).

NOTE 5 IEC 60364 provides requirements for short circuit and overload protection of the input wiring in the *installation*. The above requirement ensures that the user is informed about any special characteristics of the protective devices for the protection of the *PECS*, in addition to the requirements in IEC 60364 or other local *installation* codes.

If a protective device interrupts the neutral conductor, it shall also simultaneously interrupt all other supply conductors of the same circuit. It is permissible for the protective device to interrupt the neutral conductor after the other supply conductors of the same circuit.

Compliance shall be checked by inspection and where necessary, by simulation of *single fault conditions* (see 4.2) and by the tests of 5.2.4.4 and 5.2.4.5.

4.3.2 Specification of input short-circuit withstand strength and output short circuit current ability

4.3.2.1 General

The interrupting capability of the overcurrent protective device shall be equal or greater than the *prospective short circuit current* of the *mains supply*.

For *pluggable equipment type A*, either the *PECS* shall be designed so that the building *installation* provides *short circuit backup protection*, or additional *short circuit backup protection* shall be provided as part of the equipment.

For *permanently connected equipment* or *pluggable equipment type B*, it is permitted for *short circuit backup protection* to be in the building *installation*.

4.3.2.2 Input ports short-circuit withstand strength

The input *prospective short circuit current* ratings apply to *ports* intended to be connected to battery circuits, external *mains supply*, *non-mains* a.c. or d.c. sources, and to other *ports* for which overcurrent protection is necessary.

For co-ordination and selection of internal or external protective devices, the *PECS* manufacturer shall specify:

- a maximum allowable *prospective short circuit current* for each input *port* of the *PECS*; and
- a minimum required *prospective short circuit current* in order to ensure proper operation of the protective device

NOTE 1 This requirement is especially applicable to fuses, which are not specified to be operated below a certain fault current value.

NOTE 2 The maximum allowable and minimum required *prospective short circuit current* are used to ensure a proper coordination between the *prospective short circuit current* and a *suitable protective device* at the location of the electrical *installation*.

If external protective devices are specified or provided the characteristics of those shall be specified by the manufacturer.

See 6.2 for marking.

4.3.2.3 Output short circuit current ability

The *output short circuit current* ratings apply to a.c. and d.c. power output *ports* and to other *ports* for which overcurrent protection is necessary.

For all output *ports*, short circuit evaluation to determine the minimum and maximum *output short circuit current* shall be performed according to 5.2.4.4 and the *output short circuit current* available from the *PECS* shall be specified as in 5.2.4.4 and 6.2.

Internal electronic output short circuit protection is considered acceptable as an output short circuit protection device of the *PECS*, when compliance is shown by test in 5.2.4.4.

4.3.2.4 Combined input and output ports

For *ports* which are both input and output *ports* the applicable requirements of both 4.3.2.1 and 4.3.2.3 apply.

4.3.3 Short-circuit coordination (backup protection)

Protective devices provided or specified shall have adequate breaking capability to interrupt the maximum *prospective short circuit current* specified for the *port* to which they are connected.

If internal protection of the *PECS* is not rated for the *prospective short circuit current*, the installation instructions shall specify an upstream protective device, rated for this *prospective short circuit current* of that *port*, which shall be used to provide backup protection. Analysis shall ensure the protection coordination between the external and internal protective device.

NOTE IEC 60364 provides requirements for upstream protective devices of the backup protection in the *installation*. The above requirement ensures that the user is informed about any special characteristics of the upstream protective devices for the backup protection of the *PECS*, in addition to the requirements in IEC 60364 or other local *installation* codes.

Compliance shall be checked by inspection and by the tests of 5.2.4.4 and 5.2.4.5 .

4.3.4 Protection by several devices

Where protective devices that require manual replacement or resetting are used in more than one pole of a supply to a given load, those devices shall be located together. It is permitted to combine two or more protective devices in one component.

Compliance shall be checked by inspection.

4.4 Protection against electric shock

4.4.1 General

Protection against electric shock depends on the *decisive voltage class* from 4.4.2 and *insulation* requirements from 4.4.2.3, and is to be provided by at least one of the following measures:

- *basic protection* from 4.4.3 and *fault protection* from 4.4.4;
- *enhanced protection* from 4.4.5

Protection under normal conditions is provided by *basic protection*, and protection under *single fault conditions* is provided by *fault protection*.

Enhanced protection provides protection under both conditions.

Additional protection can be provided by residual current-operated protective devices (RCD). For further information, see 4.4.8.

NOTE In this standard, 4.4.1 to 4.4.6 have been harmonized with the concepts of the horizontal standard IEC 61140 for protection against electrical shock. *Basic protection*, *fault protection*, *enhanced protection* and the combination of those measures has been implemented.

4.4.2 Decisive voltage class

4.4.2.1 General

The probability of electric shock increases with voltage level, surface area of the accessible conductive part or circuit in contact with the skin and the humidity condition of skin. To reduce the likelihood of electric shock, it is important to determine the safe *decisive voltage class* (DVC As).

For the selection of the relevant *decisive voltage class Ax* for accessible circuits the following apply:

- the reaction of the body (see A.5);
- the area of the accessible part of the equipment in relation to the area of the part of the body that may contact the accessible part, from Table 3;
- the humidity condition of the body skin from Table 4.

The values in Table 5 are based on a current path from the contact area of the body to feet with the person in standing position.

No protection is required if:

- under normal operation, the limits derived from Table 5, and
- under *single fault condition* the limits of touch voltage limits from Figures 1 to Figure 3,

are not exceeded.

DVC Ax, as chosen in Table 5 becomes the highest voltage value permitted to be touched for the *PECS* under consideration and is so-called *DVC As* for use in this standard. Other *DVC Ax* values higher than *DVC As* shall then be treated as *DVC B*.

In this standard, values of *DVC B* and *DVC C* are not allowed to be touchable, except under dry condition with finger tip for *DVC B* as shown in Table 2.

NOTE Within the *PECS*, this standard allows more than one *DVC As* circuit with different levels of *DVC As*.

4.4.2.2 Determination of *decisive voltage class*

4.4.2.2.1 General

For protection against the *ventricular fibrillation* body reaction, *DVC* can be selected from Table 2. For less severe reactions of the body, more information is given in A.5.

If it is impossible to protect against the body reaction relevant to the *DVC As*, a *basic protection* against accessibility to *hazardous live parts* according to 4.4.3 is required.

The *DVC* voltage limits for the steady-state values under normal operation from Table 2 are given in Table 5. The short term non-recurring touch voltage limits are given in Figure 1 to Figure 3.

Table 2 – Selection of *DVC* for touch voltage to protect against *ventricular fibrillation*

Body skin humidity conditions	Body contact area		
	Part of the body	Hand	Finger tip
Dry	<i>DVC A2</i>	<i>DVC A</i>	<i>DVC B</i>
Water wet	<i>DVC A1</i>	<i>DVC A2</i>	<i>DVC A</i>
Saltwater wet	<i>Basic protection</i> against accessibility is required	<i>DVC A1</i>	<i>DVC A2</i>

4.4.2.2.2 Selection tables for contact area and skin humidity condition

In order to protect against *ventricular fibrillation*, the appropriate conditions from Table 3 and Table 4 shall be selected.

If this standard is used for a product for which no product standard exists, select “Hand” for the contact area and “Dry” for the skin humidity condition. When a product for which no product

standard exists is identified for use where the skin and humidity condition and/or the body contact area are other than “Hand” or “Dry”, then those conditions shall be selected from Table 3 and Table 4.

Table 3 – Selection of body contact area

Contact area of accessible parts		
Finger tip cm ²	Hand cm ²	Part of the body cm ²
accessible parts < 1	1 < accessible parts < 80	80 < accessible parts < 500
NOTE In order to match several basic standards, dealing with Small, Medium and Large contact areas, this standard is using Finger tip instead of Small, Hand instead of Medium and Part of the body instead of Large.		

Table 4 – Selection of humidity condition of the skin

Humidity condition of the skin		
Dry	Water wet	Saltwater wet
normal indoor condition	immersed for more than 1 min in normal water (average value $\rho = 35 \Omega\text{cm}$, pH = 7,7 to 9)	immersed for more than 1 min in a solution of 3 % NaCl in water (average value $\rho = 0,25 \Omega\text{cm}$, pH = 7,5 to 8,5)
NOTE 1 For selection of skin humidity condition Table 18 provides the relevant skin condition related to the service environment condition.		
NOTE 2 Information and values are taken from IEC 60479-1		

4.4.2.2.3 Limits of the *working voltage* for the *DVC*

Limits for the *working voltage* regarding the *DVC* for normal operation are given in Table 5.

Table 5 – Steady state voltage limits for the *decisive voltage classes*

<i>DVC</i>	Limits of <i>working voltage</i> V		
	AC voltage (r.m.s.) U_{ACL}	AC voltage (peak) U_{ACPL}	DC voltage (mean) U_{DCL}
A1	8	11,3	22
A2	12	17	28
A3	20	28,3	48
A	30 ^a	42,4	60
B	50	71	120
C	>50	>71	>120
NOTE In some standards <i>SELV</i> and <i>PELV</i> have similar limits to <i>DVC B</i> .			
^a In this standard the <i>DVC A</i> limits are considered for one circuit only. When more than one <i>DVC A</i> circuit of the <i>PECS</i> is accessible and evaluation from 4.2 shows that the voltage of the two circuit can add together under <i>single fault condition</i> , the limit is 25V for a.c. voltage r.m.s.			

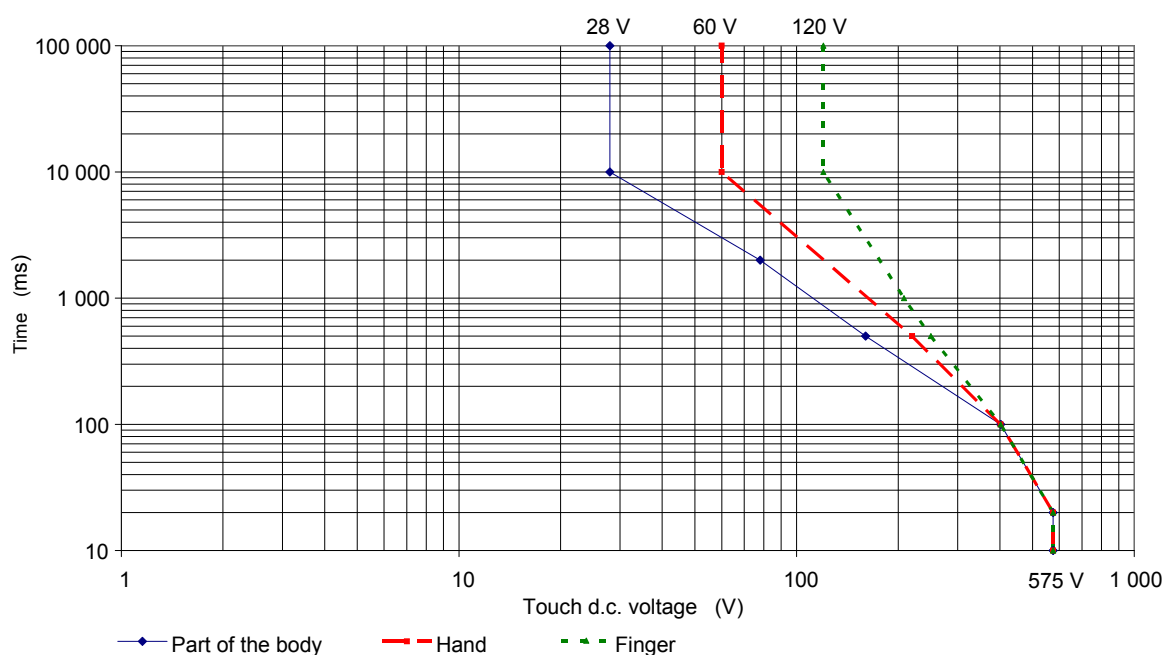
A.6 shows three examples of different waveforms of *working voltage* and provides methods to evaluate the voltage under consideration to match with the *DVC* levels.

The short term non-recurring touch voltages limits during a single fault are given in Figure 1, Figure 2 and Figure 3.

Within 10 000 ms, the voltage has to decrease to the steady state value given in Table 5.

Table 5, or the fault is to be interrupted by a protective device. Under fault conditions where a protective device is used the characteristics of such device shall ensure that the time-voltage limits given in Figure 1 to Figure 3 are not exceeded. If an external protective device is used, information on characteristics of such device shall be specified by the *PECS* manufacturer in the installation manual according to 6.3.7.7.

NOTE 1 Figure 1 to Figure 3 only provide d.c. values for touch voltage because most frequent touchable voltage are d.c. values. If the manufacturer needs values for a.c. voltage, see A.5.5.



IEC 1205/12

Figure 1 – Touch time - d.c. peak voltage zones of ventricular fibrillation in dry skin condition

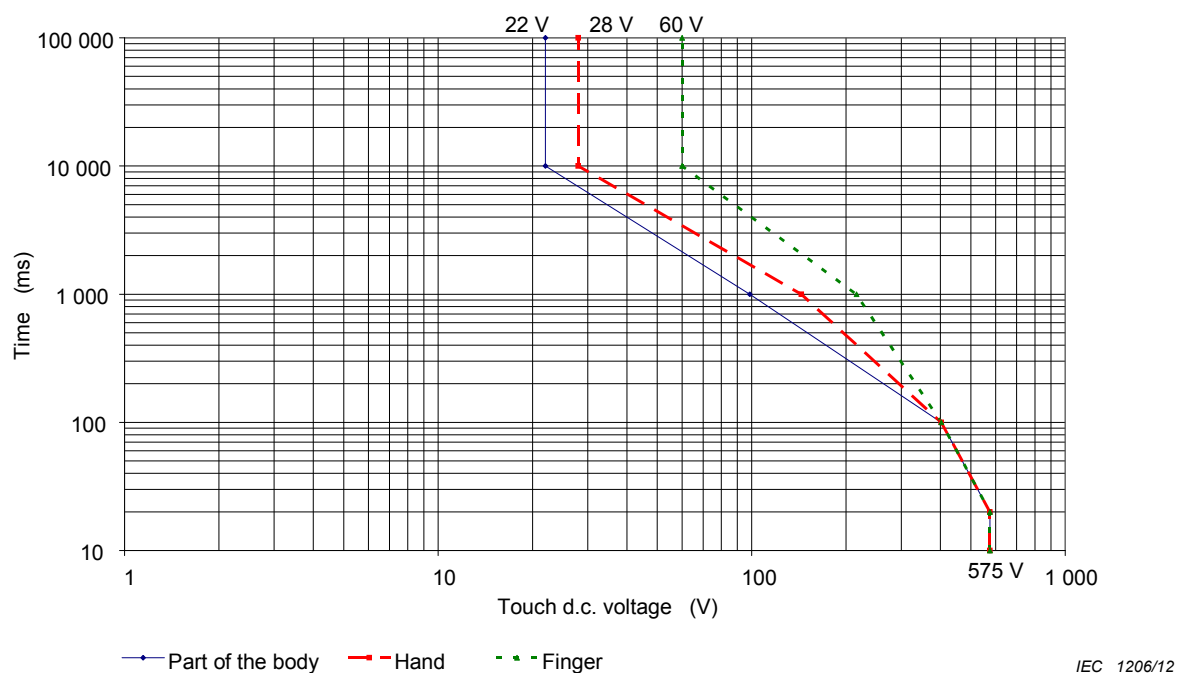


Figure 2 – Touch time - d.c. peak voltage zones of ventricular fibrillation in water-wet skin condition

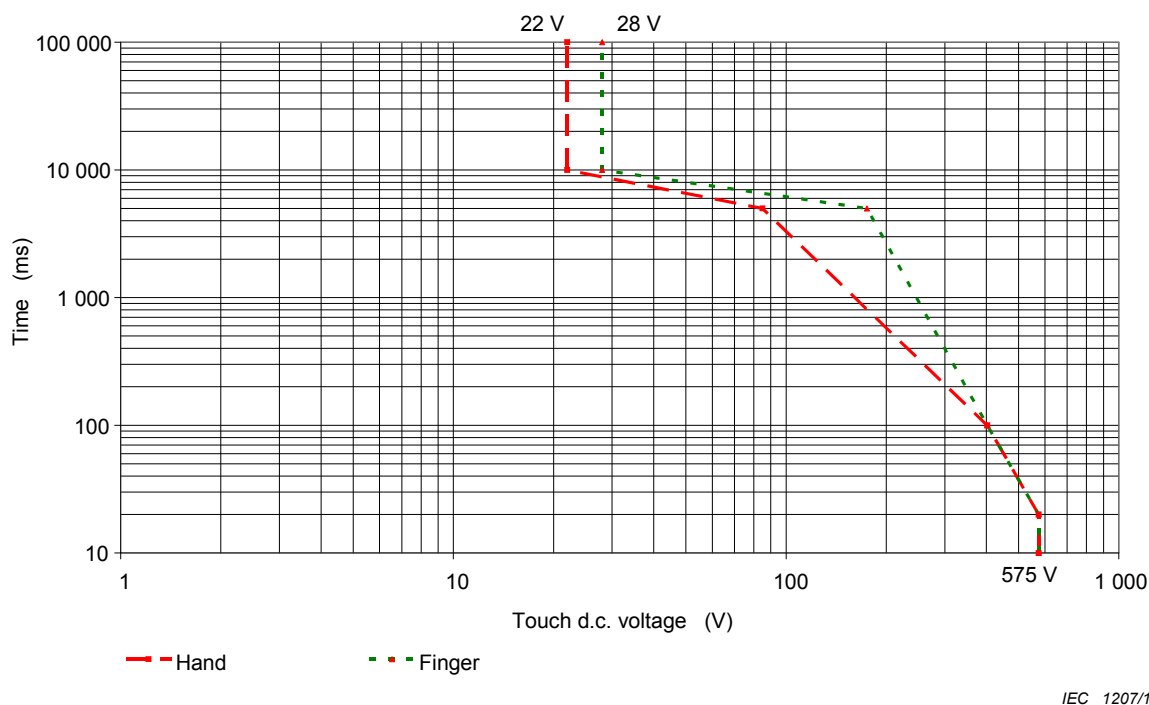


Figure 3 – Touch time - d.c. peak voltage zones of ventricular fibrillation in saltwater-wet skin condition

For part of the body, no information for time-voltage zone is given. *Basic protection* against accessibility is required.

For testing, see 5.2.4.

If the test results in a failure, additional measure is required for protection against electric shock according to 4.4.3.

4.4.2.3 Requirements for protection against electric shock

Table 6 shows possible solutions for compliance with 4.4 for the application of *simple* or *protective separation*, dependent on the *DVC* of the circuit under consideration and of *adjacent circuits*.

The requirements of this standard for protection against electric shock may be fulfilled by other means than shown in Table 6, in which case failure analysis and testing shall show that the requirements of 4.1 and 4.4 are met.

Table 6 – Protection requirements for circuit under consideration

DVC of circuit under consideration	Protection against accessibility	Protection to accessible conductive parts connected to PE	Protection to accessible conductive parts that are not connected to PE ^g	Protection to <i>adjacent circuit</i> of DVC:		
				As ^a	B or Ax > As	C
As ^a	No	1 ^b	1	1 ^c or 2 ^d	2	enhanced protection
B or Ax > As	basic protection ^e	basic protection ^e	basic protection		1 ^c or 2 ^d	enhanced protection
C	enhanced protection	basic protection	enhanced protection			1 or 2 ^f

NOTE 1

1 Protection is not necessary for safety, but may be required for functional reasons according to 4.4.7.3.

2 Basic protection for circuit of higher voltage.

1 or 2 Depending on separation with other circuits.

NOTE 2 Ax > As Voltage less than DVC B but higher than DVC As, that does not meet 4.4.2.2.

^a A, A1, A2 or A3, which ever is appropriate according to 4.4.2.2.

^b If the considered circuit is designated as a SELV circuit, basic protection is required from earth and from PELV circuits.

^c Both circuits under consideration have the same DVC As level.

^d Both circuits under consideration have different DVC As level.

^e Except for Finger tip. See Table 2.

^f Basic protection is required between galvanically isolated circuits (e.g. mains supply, UPS output, PV or generator output, auxiliaries).

^g Also applies to conductive parts connected to functional earth.

To ensure the integrity of the *insulation* of the *PECS*, the manufacturer of a *PECS* shall state the maximum voltage allowed to be connected to each *port*. See 6.3.7.1 for marking.

4.4.3 Provision for basic protection

4.4.3.1 General

Basic protection is employed to prevent persons from touching *hazardous live parts*. It shall be provided by one or more of the measures given in:

- Protection by means of *basic insulation* of live parts in 4.4.3.2;
- Protection by means of *enclosures* or barriers in 4.4.3.3;
- Protection by means of limitation of touch current and charge in 4.4.3.4;
- Protection by means of limited voltages in 4.4.3.5.

NOTE Further measures to fulfill the requirement for *basic protection* are given in IEC 61140. Product committees using this document as reference document might consider those measures.

4.4.3.2 Protection by means of *basic insulation of live parts*

Live parts shall be completely surrounded with *insulation* if their *working voltage* is greater than *DVC As* or if they do not have *protective separation* from *adjacent circuits* of *DVC C*.

Basic insulation may be provided by solid *insulation* or air clearance.

The *insulation* shall be rated according to the impulse voltage, *temporary overvoltage* or *working voltage* (see 4.4.7.2.1), whichever gives the most severe requirement. It shall not be possible to remove the *insulation* without the use of a tool or key.

An accessible conductive part is considered to be conductive if its surface is bare or is covered by an insulating layer that does not comply with the requirements of at least *basic insulation*.

Any accessible conductive part is considered to be a *hazardous live part* if not separated from the *live parts* by at least as specified in Table 6.

The *basic insulation* shall be designed and tested to withstand the impulse voltages and *temporary overvoltages* for the circuits to which they are connected. See 5.2.3.2 and 5.2.3.4 for tests.

A.7 provides examples of the use of elements of protective measures.

4.4.3.3 Protection by means of *enclosures or barriers*

Live parts with voltage higher than *DVC As* shall be:

- arranged in *enclosures* or located behind *enclosures* or barriers, which meet at least the requirements of the Protective Type IPXXB according to Clause 7 of IEC 60529:1989;
- located at 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.

For moveable equipment with no defined top and bottom this requirement of protective Type IP3X applies to all sides.

If the *PECS* is installed in a *restricted access area*, IPXXB instead of IP3X applies.

Product committees using this document as reference document might consider less requirement for equipment having openings in the top of an *enclosure* with a height exceeding 1,8 m.

Compliance is shown by test of 5.2.2.2.

It shall only be possible to open *enclosures* or remove barriers:

- with the use of a tool or key; or
- after de-energization of these *live parts*.

Where the *enclosure* is required to be opened and the *PECS* energized during installation or maintenance:

- a) accessible *live parts* of voltage higher than *DVC As* shall be protected by at least IPXXA;

- b) *live parts* of voltage higher than *DVC As* that are likely to be touched when making adjustments shall be protected by at least IPXXB;
- c) it shall be ensured that persons are aware that *live parts* with voltage higher than *DVC As* are accessible.

Open type sub-assemblies and equipment do not require protective measures for *basic protection*. The information provided with the *PECS* shall indicate that protection shall be provided in the end application.

For marking requirements, see 6.3.7.1.

Products containing circuits of *DVC A, B* or *C*, intended for installation in *restricted access areas* as defined in 3.48, need not have protective measures for *basic protection*.

4.4.3.4 Protection by means of limitation of *touch current* and charge

The limitation of *touch current* and discharge energy shall not exceed:

- a value of 3,5 mA a.c. or 10 mA d.c. for the limitation of *touch current*; and
- a value of 50 µC for the limitation of discharge energy.

See A.3 and A.4 for examples of these measures.

NOTE 1 The value of the *touch current* is independent of the *DVC Ax*.

NOTE 2 Product committees using this document as reference document may consider the *touch current* level of 0,5 mA a.c. / 2 mA d.c. as threshold of perception as recommended by IEC 61140.

4.4.3.5 Protection by means of limited voltages

The voltage between simultaneously accessible parts shall not be greater than *DVC As* as determined in 4.4.2.2.

See A.2, A.3 and A.4 for examples of these measures.

4.4.4 Provision for *fault protection*

4.4.4.1 General

Fault protection is required to prevent shock currents which can result from contact with accessible conductive parts during and after an *insulation* failure.

Fault protection shall be provided by one or more of the following measures:

- *Protective equipotential bonding* in 4.4.4.2 in combinations with the *PE conductor* in 4.4.4.3;
- Automatic disconnection of supply in 4.4.4.4;
- *Supplementary insulation* in 4.4.4.5;
- Simple separation between circuits in 4.4.4.6;
- Electrically *protective screening* in 4.4.4.7.

Fault protection shall be independent and additional to those for *basic protection*.

NOTE Further measures to fulfill the requirement for *fault protection* are given in IEC 61140. Product committees using this document as reference document might consider those measures.

4.4.4.2 **Protective equipotential bonding**

4.4.4.2.1 **General**

Protective equipotential bonding shall be provided between accessible conductive parts of the equipment and the means of connection for the *PE conductor*, except:

- a) accessible conductive parts that are protected by one of the measures in 4.4.6.4; or
- b) when accessible conductive parts are separated from *live parts* using *double* or *reinforced insulation*.

Electrical contact to the means of connection of the *PE conductor* shall be achieved by one or more of the following means:

- through direct metallic contact;
- through other accessible conductive parts or other metallic components which are not removed when the *PECS* is used as intended;
- through a dedicated *protective equipotential bonding* conductor.

When painted surfaces (in particular powder painted surfaces) are joined together, masking of paint, paint piercing methods or a separate connection shall be made to ensure reliable contact.

Where electrical equipment is mounted on lids, doors, or cover plates, continuity of the *protective equipotential bonding* circuit shall be ensured by a dedicated conductor or equivalent means complying with the requirements for *protective equipotential bonding*. If fasteners, hinges or sliding contacts do not provide and guarantee low enough impedance, sufficient parallel bonding is required.

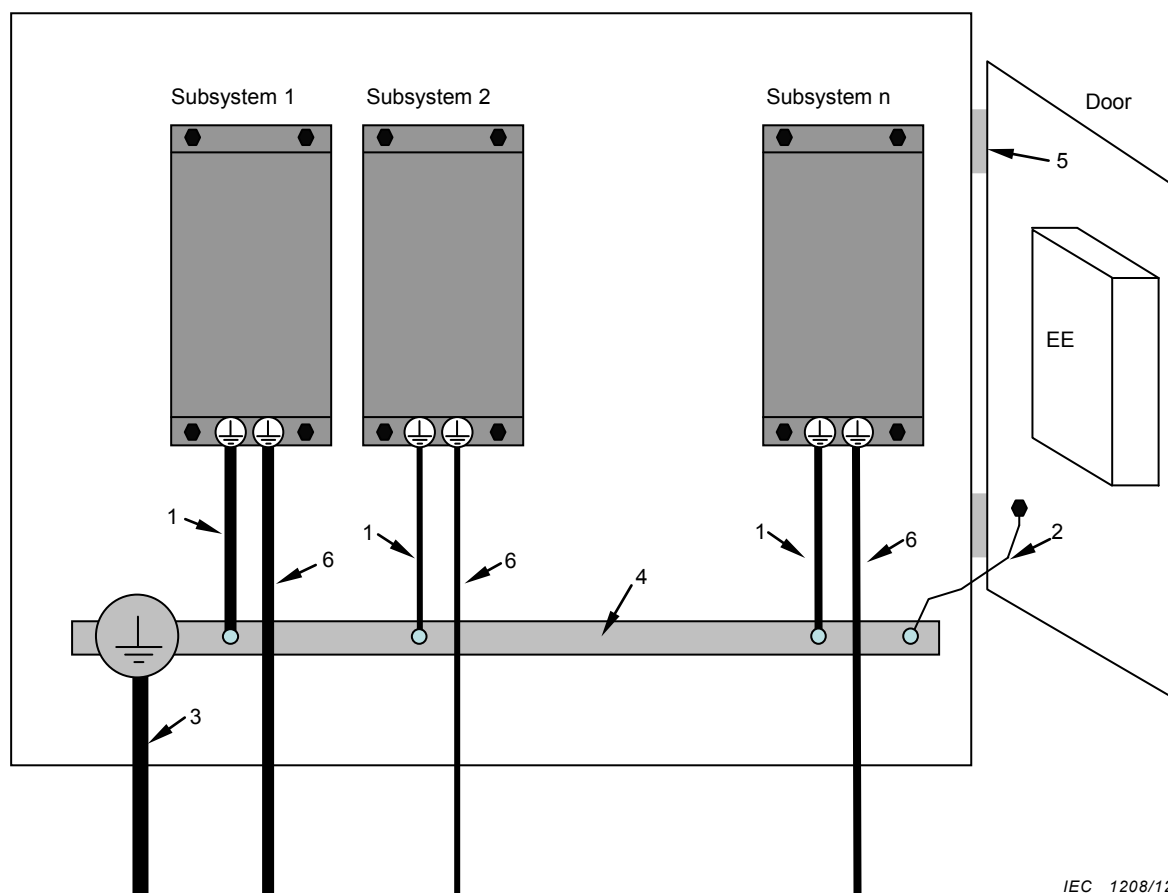
Electrical connections of *protective equipotential bonding* circuit shall be designed so that contact pressure is not transmitted through insulating material, unless there is sufficient resilience in the metallic parts to compensate for any possible shrinkage or distortion of the insulating material.

Unless specified by the manufacturer and in compliance with 4.4.4.2.2 metal ducts of flexible or rigid construction and metallic cable sheaths shall not be used as *protective equipotential bonding* means. Nevertheless, such metal ducts and the metal sheathing of all connecting cables (for example cable armouring, lead sheath) shall be connected to the *protective equipotential bonding* circuit.

The *protective equipotential bonding* circuit shall not incorporate a component such as switch or overcurrent protective devices which may open the circuit.

The electrical connection points of the *protective equipotential bonding* shall be corrosion-resistant.

Figure 4 shows an example of a *PECS* assembly and its associated *protective equipotential bonding*.

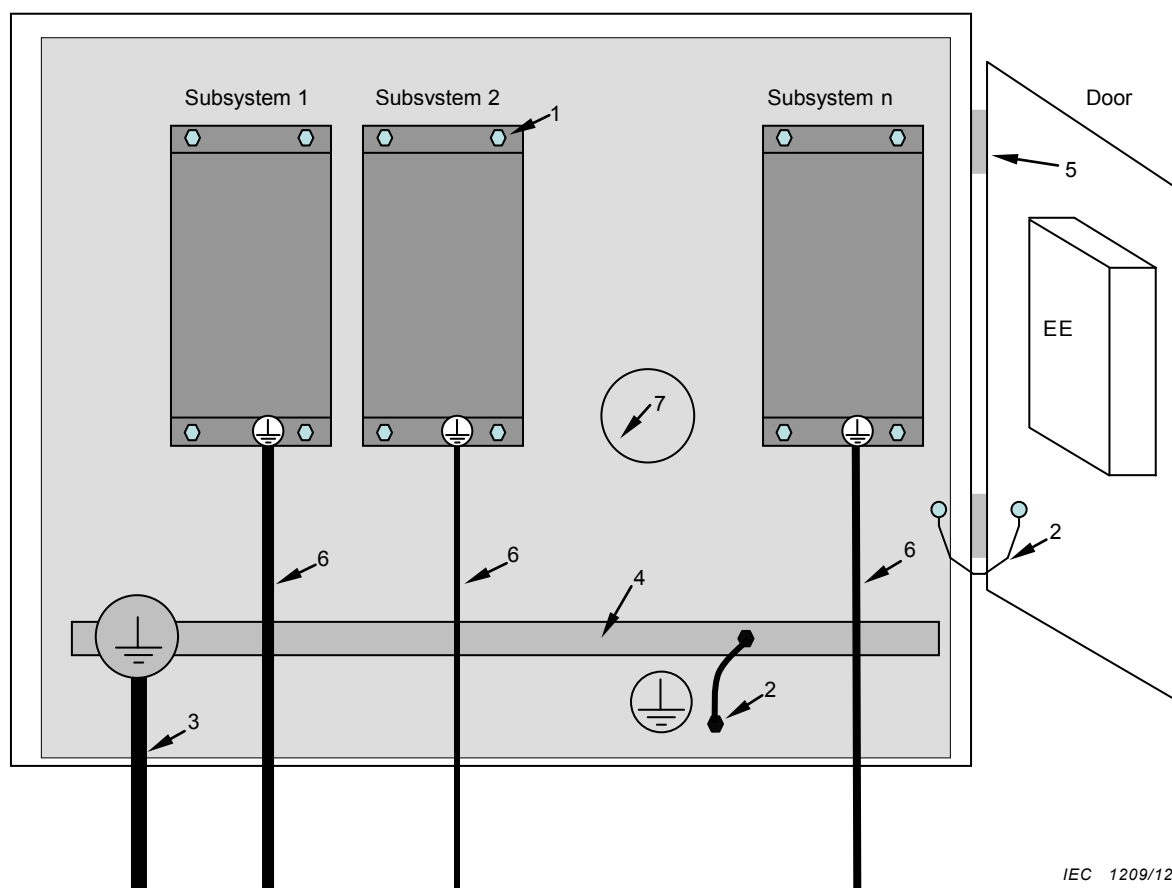


Key

- 1 *protective equipotential bonding of subsystems or PECS PE conductor (dimensioned according to PECS requirements)*
- 2 *protective equipotential bonding*
- 3 *PE conductor (dimensioned according to PECS requirements) to installation earthing point*
- 4 *earth bar*
- 5 *hinge*
- 6 *PE conductor to the load*
- EE *other electrical equipment (bonded as relevant for that equipment)*

Figure 4 – Example of a PECS assembly and its associated protective equipotential bonding

Figure 5 shows an example of a PECS assembly and its associated *protective equipotential bonding* through direct metallic contact.



Key

- | | |
|----|---|
| 1 | <i>protective equipotential bonding</i> of subsystems through direct metallic contact (paint removed) |
| 2 | <i>protective equipotential bonding</i> |
| 3 | <i>PE conductor</i> (dimensioned according to <i>PECS</i> requirements) to <i>installation</i> earthing point |
| 4 | <i>earth bar</i> |
| 5 | hinge |
| 6 | <i>PE conductor</i> to the load |
| 7 | metal subplate |
| EE | other electrical equipment (bonded as relevant for that equipment) |

Figure 5 – Example of a *PECS* assembly and its associated *protective equipotential bonding*

4.4.4.2.2 Rating of *protective equipotential bonding*

Protective equipotential bonding shall either be:

- a) sized in accordance with the requirements for the *PE conductor* in 4.4.4.3 and the means of connection for the *PE conductor* in 4.4.4.3.2 to ensure no voltage drop exceeding the values from 4.4.2.2.3 during a fault; or
- b) sized
 - to withstand the highest stresses that can occur to the *PECS* item(s) concerned when they are subjected to a fault connecting to accessible conductive parts; and
 - to remain effective for as long as a fault to the accessible conductive parts persists or until an upstream protective device removes power from the part; and

- to ensure no voltage drop exceeding the values from 4.4.2.2.3 during normal operation and during a fault.

Compliance shall be checked with the *type tests* in 5.2.3.11.

4.4.4.3 PE conductor

4.4.4.3.1 General

A *PE conductor* shall be connected at all times when power is supplied to the *PECS*, unless the *PECS* complies with the requirements of *protective class II* (see 4.4.6.3) or *protective class III*. Unless local wiring regulations state otherwise, the *PE conductor* cross-sectional area shall be determined from Table 7 or by calculation according to 543.1 of IEC 60364-5-54:2011.

If the *PE conductor* is routed through a plug and socket, or similar means of disconnection, it shall not be possible to disconnect it unless power is simultaneously removed from the part to be protected.

Table 7 – PE conductor cross-section^a

Cross-sectional area of phase conductors of the <i>PECS</i> S mm ²	Minimum cross-sectional area of the corresponding <i>PE conductor</i> S_p mm ²
$S \leq 16$	S
$16 < S \leq 35$	16
$35 < S$	$S/2$
^a These values are valid only if the <i>PE conductor</i> is made of the same material as the phase conductors. In case of different materials the cross-sectional area of the <i>PE conductor</i> shall be determined in a manner which produces a conductance equivalent to that which results from the application of this table.	

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

- 2,5 mm² if mechanical protection is provided; or
- 4 mm² if mechanical protection is not provided.

Provisions within cord-connected equipment shall be made so that the *PE conductor* in the cord shall, in the case of failure of the strain-relief mechanism, be the last conductor to be interrupted.

For special *system* topologies, the *PECS* designer shall verify the *PE conductor* cross-section required.

4.4.4.3.2 Means of connection for the PE conductor

PECS shall have a means of connection for the *PE 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 conductors according to Table 7 and of cables in accordance with the wiring rules applicable at the *installation*. The means of connection for the *PE conductor* shall not be used as a part of the mechanical assembly of the equipment or for other connections. Connection and bonding points shall be designed so 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.

Compliance shall be checked by inspection.

Annex K provides further information about electrochemical corrosion.

See 6.3.7.3.2 for marking requirements.

The marking shall not be placed on or fixed by screws, washers or other parts which might be removed when conductors are being connected.

4.4.4.3.3 Touch current in case of failure of PE conductor

The requirements of this subclause shall be satisfied to prevent accessible conductive parts to become dangerous in case of damage to or disconnection of the *PE conductor*.

For *pluggable type A* equipment, the *touch current* shall not exceed the limits specified in 4.4.3.4

For all other *PECS*, one or more of the following measures shall be applied, unless the *touch current* can be shown to be less than the limits specified in 4.4.3.4:

a) Use of a fixed connection and

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

or

b) Use of a *pluggable type B* connection with a minimum *PE conductor* cross-section of 2,5 mm² as part of a multi-conductor power cable. Adequate strain relief shall be provided.

For marking requirements, see 6.3.7.4.

Compliance is checked by inspection and by test of 5.2.3.7.

For equipment which may be energized from multiple sources of supply, the *touch current* limits above apply in all possible intended *installation* configurations and combinations of sources that may be energized at the same time, unless one of the measures in a) or b) above is used.

When it is intended and allowed to interconnect two or more *PECS* using one common *PE conductor*, the above *touch current* requirements apply to the maximum number of *PECS* to be interconnected, unless one of the measures in a) or b) above is used. The maximum number of interconnected *PECS* is used in the testing and has to be stated in the installation manual.

4.4.4.4 Automatic disconnection of supply

For automatic disconnection of supply:

- a *protective equipotential bonding system* shall be provided; and
- a protective device operated by the fault current shall disconnect one or more of the line conductors supplying the equipment, *system* or *installation*, in case of a failure of *basic insulation*.

The protective device shall interrupt the fault current within a time as specified in Figure 1, Figure 2 or Figure 3 in 4.4.2.2.3.

4.4.4.5 Supplementary insulation

Supplementary insulation is an independent *insulation* applied in addition to *basic insulation* for *fault protection* and shall be dimensioned to withstand the same stresses as specified for *basic insulation*.

4.4.4.6 Simple separation between circuits

Simple separation between a circuit and other circuits or earth shall be achieved by *basic insulation* throughout, rated for the highest voltage present.

If any component is connected between the separated circuits, that component shall withstand the electric stresses specified for the insulation which it bridges.

If any component is connected between a circuit and a circuit connected to earth, its impedance shall limit the current flow through the component to the steady-state *touch current* values indicated in 4.4.3.4.

4.4.4.7 Electrically protective screening

Electrically protective screening interposed between *hazardous live parts* of a PECS, shall consist of a conductive screen connected to the *protective equipotential bonding* of the PECS whereby the screen is separated from *live parts* by at least *simple separation*.

The protective screen and the connection to the *protective equipotential bonding system* of the PECS and that interconnection shall comply with the requirements of 4.4.4.2.

4.4.5 Enhanced protection

4.4.5.1 General

Enhanced protection shall provide both *basic* and *fault protection* and can be achieved by means of:

- Reinforced insulation in 4.4.5.2;
- Protective separation between circuits in 4.4.5.3;
- Protection by means of in 4.4.5.4.

NOTE Further measures to fulfil the requirement for *enhanced protection* are given in IEC 61140. Product committees using this document as reference document might consider those measures.

4.4.5.2 Reinforced insulation

Reinforced insulation shall be so designed as to be able to withstand electric, thermal, mechanical and environmental stresses with the same reliability of protection as provided by *double insulation* (*basic insulation* and *supplementary insulation*, see 4.4.3.2 and 4.4.4.5).

4.4.5.3 Protective separation between circuits

Protective separation between a circuit and other circuits shall be achieved by one of the following means:

- *double insulation* (*basic insulation* and *supplementary insulation* in 4.4.3.2 and 4.4.4.5);
- *reinforced insulation* in 4.4.5.2;
- *electrically protective screening* in 4.4.4.7;
- a combination of these provisions.

If conductors of the separated circuit are contained together with conductors of other circuits in a multi-conductor cable or in another grouping of conductors, they shall be insulated, individually or collectively, for the highest voltage present, so that *double insulation* is achieved.

If any component is connected between the separated circuits, that component shall comply with the requirements for *protective impedance* devices (see 4.4.5.4)

4.4.5.4 Protection by means of *protective impedance*

Protective impedance shall be arranged so that under both normal and *single fault conditions* the current and discharge energy available shall be limited according to 4.4.3.4.

The *protective impedances* shall be designed and tested to withstand the impulse voltages and *temporary overvoltages* for the circuits to which they are connected. See 5.2.3.2 and 5.2.3.4 for tests.

Compliance with the requirement for the limitation of *touch current* is checked by test of 5.2.3.6.

Compliance with the requirement for the discharge energy shall be checked by performing calculations and/or measurements to determine the voltage and capacitance.

NOTE A *protective impedance* designed according to this subclause is not considered to be a galvanic connection.

4.4.6 Protective measures

4.4.6.1 General

That part of a *PECS* which meets the requirements of 4.4.6.2 is defined as *protective class I*.

That part of a *PECS* which meets the requirements of 4.4.6.3 is defined as *protective class II*.

That part of a *PECS* which meets the requirements of 4.4.6.4 is defined as *protective class III*.

Compliance shall be checked by satisfying the requirements for *protective class I*, *class II* or *class III*.

A.7 provides Examples of the use of elements of protective measures.

Equipment of *protective class I*, *II* and *III* shall be marked according to 6.3.7.3.

4.4.6.2 Protective measures for *protective class I* equipment

Protective class I equipment shall meet the requirements for:

- *basic protection* in 4.4.3; and
- *fault protection* in 4.4.4.2 and 4.4.4.3 with respect to equipotential bonding and *PE conductor*.

4.4.6.3 Protective measures for *protective class II* equipment

Protective class II equipment shall meet the requirements for *enhanced protection* according to 4.4.5 and the *enclosure* shall meet the requirement for *basic protection* in 4.4.3 with respect to accessibility to *hazardous live parts*.

Protective class II equipment shall not have means of connection for the *PE conductor*. This does not apply if a *PE conductor* is passed through the equipment to equipment series-connected beyond it.

In the latter case the *PE conductor* and its means for connection shall be separated from:

- accessible surface of the equipment; and
- circuits which employ *protective separation*

with at least *simple separation* according to the requirement in 4.4.4.6.

The *simple separation* shall be designed according to the rated voltage of the series-connected equipment.

Equipment of *protective class II* may have provision for the connection of an earthing conductor for functional reasons or for the damping of overvoltages. In this case, the functional earthing conductor shall be separated from:

- accessible surface of the equipment; and
- circuits which employ *protective separation* according to 4.4.5.3

with at least *protective separation* according to the requirement in 4.4.5.3.

Equipment of *protective class II* shall be marked according to 6.3.7.3.3.

Compliance is checked by inspection.

4.4.6.4 Protective measures for *protective class III* equipment or circuits

4.4.6.4.1 General

Protective measures shall be achieved by *protective separation* by one of the following means:

- *basic insulation* and *supplementary insulation* (*double insulation*) according to 4.4.3.2 and 4.4.4.5;
- *reinforced insulation* according to 4.4.5.2;
- *electrically protective screening* and *simple separation* according to 4.4.4.7; or
- a combination of these provisions;

used in combination with one of the following means:

- *protective impedance* according to 4.4.5.4 comprising limitation of discharge energy and of current; or
- limitation of voltage according to 4.4.3.5.

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

4.4.6.4.2 Connection to *PELV* and *SELV* circuits

If a *port* is intended for connection of an external *PELV* or *SELV* circuit with a higher voltage than *DVC As*:

- measures to limit the voltage to that of *DVC As* shall be taken (see Annex A); or
- *basic protection* shall be provided.

For connectors containing pins with very small contact area ($< 1 \text{ mm}^2$), the next higher voltage level for *DVC As*, of Table 5, is permitted. Example: if *DVC A1* is *DVC As*, then *DVC A2* is permitted at pins of signal connectors.

The connection of external *PELV* or *SELV* circuits to an internal circuit is permitted with the following consideration:

- without measures: only if the *DVC* of the *PELV* and *SELV* voltage are lower than or equal to the *DVC* selected from Table 5 for the internal circuit under consideration; and
- with measures: if the *DVC* of the *PELV* and *SELV* voltage are higher than the *DVC* selected from Table 5 for the internal circuit under consideration.

The possibility of an addition of the voltages of the circuits under consideration to a higher level under fault conditions shall be considered.

For marking, see 6.3.7.1.

Consideration needs to be given to factors such as whether the circuits involved are earthed or not, what the voltages involved are, whether or not direct contact with live parts is possible, single faults in either equipment or the interconnections, etc.

4.4.7 Insulation

4.4.7.1 General

4.4.7.1.1 Influencing factors

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

Manufacturing tolerances shall be taken into account for the requirements in 4.4.7.

Insulation shall be selected after consideration of the following influences:

- pollution degree;
- overvoltage category;
- supply *system* earthing;
- impulse withstand voltage, *temporary overvoltage* and *working voltage*;
- location of *insulation*;
- type of *insulation*.

Verification of *insulation* shall be made according to 5.2.2.1, 5.2.3.2, 5.2.3.4, and 5.2.3.5.

4.4.7.1.2 Pollution degree

Insulation, especially when provided by clearances and creepage distances, is affected by pollution which occurs during the *expected lifetime* of the *PECS*. The micro-environmental conditions for *insulation* shall be applied according to Table 8.

Table 8 – 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.
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.

The pollution degree shall be determined according to the environmental condition for which the product is specified. See Table 18 for selection of pollution degree according to environmental classification of the *installation*.

The *insulation* may be determined according to pollution degree 2 if one of the following applies:

- a) instructions are provided with the *PECS* indicating that it shall be installed in a pollution degree 2 environment; or
- b) the specific *installation* application of the *PECS* is known to be a pollution degree 2 environment; or
- c) the *PECS enclosure* or coatings applied within the *PECS* according to 4.4.7.8.4.2 or 4.4.7.8.6 provide adequate protection against what is expected in pollution degree 3 and 4 (conductive pollution and condensation).

The *PECS* manufacturer shall state in the documentation the pollution degree for which the *PECS* has been designed.

If operation in a pollution degree 4 environment is required, protection against conductive pollution shall be provided by means of a suitable *enclosure*.

NOTE 1 See Annex B for further information about the reduction of pollution degree.

NOTE 2 The dimensions for creepage distance cannot be specified where permanently conductive pollution is present (pollution degree 4). For temporarily conductive pollution (pollution degree 3), the surface of the *insulation* may be designed to avoid a continuous path of conductive pollution, e.g. by means of ribs and grooves. Annex D provides further information about the evaluation of clearance and creepage distances.

4.4.7.1.3 Overvoltage category (OVC)

The concept of overvoltage categories (based on IEC 60364-4-44 and IEC 60664-1) is used for equipment energized from the supply mains, and addresses the level of overvoltage protection expected. The OVC for *non-mains supply* is determined by taking into account whether control of overvoltages is provided or not, and whether the *PECS* is connected to outdoor lines or not, and if so, the length of the lines.

Four categories are considered.

- Equipment of overvoltage category IV (OVC IV) is for use at the origin of the *installation*.

NOTE 1 Examples of such equipment are electricity meters and primary overcurrent protection equipment and other equipment connected directly to outdoor open lines.

- Equipment of overvoltage category III (OVC III) is equipment in fixed *installations* and for cases where the reliability and the availability of the equipment are subject to special requirements.

NOTE 2 Examples of such equipment are switches in the fixed *installation* and equipment for industrial use with permanent connection to the fixed *installation*.

- Equipment of overvoltage category II (OVC II) is energy-consuming equipment to be supplied from the fixed *installation*.

NOTE 3 Examples of such equipment are appliances, portable tools and other household and similar loads.

If such equipment is subjected to special requirements with regard to reliability and availability, overvoltage category III applies.

- Equipment of overvoltage category I (OVC I) is equipment for connection to circuits in which measures are taken to limit transient overvoltages to an appropriately low level.

NOTE 4 Examples of such equipment are those containing electronic circuits protected to this level.

NOTE 5 Unless the circuits are designed to take the *temporary overvoltages* into account, equipment of overvoltage category 1 cannot be directly connected to the supply mains.

The measures for reduction of the impulse voltage shall ensure that the *temporary overvoltages* that could occur are sufficiently limited so that their peak value does not exceed the relevant rated impulse voltage of Table 9 and shall meet the requirement of 4.4.7.2.2, 4.4.7.2.3 and 4.4.7.3 as applicable.

Annex I shows examples of overvoltage category considerations for *insulation* requirements.

For *PECS* and circuits not intended to be powered from the supply mains, the appropriate overvoltage category shall be determined as required by the application based on the overvoltage control provided on the supply to the equipment or circuit.

NOTE 6 Product committees using this standard as a reference document should consider the determination of overvoltage categories for special applications.

4.4.7.1.4 Supply system earthing

The following three basic types of *system* earthing are described in IEC 60364-1.

- *TN system*: has one point directly earthed, the accessible 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 accessible 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 accessible conductive parts of the *installation* being earthed independently or collectively to the *system* earthing.

4.4.7.1.5 Determination of impulse withstand voltage and *temporary overvoltage*

Table 9 uses the *system voltage* (see 4.4.7.1.6) and overvoltage category of the circuit under consideration to determine the impulse withstand voltage. The *system voltage* is also used to determine the *temporary overvoltage*.

A *PECS* having more than one input or output shall be evaluated according to the input or output which gives the most severe requirements.

Table 9 – Impulse withstand voltage and *temporary overvoltage* versus system voltage

Column 1		2	3	4	5	6
System voltage ^a V (see 4.4.7.1.6) Up to and including		Impulse withstand voltage V				Temporary overvoltage ^b V
		Overvoltage category				
a.c.	d.c.	I	II	III	IV	r.m.s. / peak
50	75	330	500	800	1 500	1 250 / 1 770
100	150	500	800	1 500	2 500	1 300 / 1 840
150	225	800	1 500	2 500	4 000	1 350 / 1 910
300	450	1 500	2 500	4 000	6 000	1 500 / 2 120
600	900	2 500	4 000	6 000	8 000	1 800 / 2 550
1 000 ^c	1 500	4 000	6 000	8 000	12 000	2 200 / 3 110

^a Interpolation of *system voltage* is not permitted when determining the impulse withstand voltage for *mains supply*.

^b The r.m.s. values are derived using the formula (1 200 V + *system voltage*) from IEC 60664-1.

^c The last row only applies to single-phase *systems*, or to the phase-to-phase voltage in three-phase *systems*.

4.4.7.1.6 Determination of the system voltage

4.4.7.1.6.1 For *mains supply*

For *PECS* supplied by an a.c. *mains supply*, the *system voltage* (in column 1 of Table 9) is:

- in TN and TT *systems*, the r.m.s. value of the rated voltage between a phase and earth;

NOTE 1 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 (i.e. the phase-phase voltage).

- 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);

NOTE 2 For most *systems*, this is equivalent to dividing the phase-to-phase voltage by $\sqrt{3}$.

NOTE 3 The phase to an artificial neutral point can be accepted due to the well balance *systems*. Under *single fault condition* the *system voltage* will temporary change to phase to phase voltage, but under this *single fault condition* the impulse voltage is allowed to be reduced by one step according to Table 9 and will lead to the same result for the determination of clearance.

- the r.m.s. value of the rated voltage between phases for *PECS* with increased reliability;
- 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 supply conductors.

NOTE 4 For *PECS* having series-connected diode bridges (12-pulse, 18-pulse, etc.), the *system voltage* is the sum of the a.c. voltages at the diode bridges.

When the supply voltage is rectified d.c. derived from the a.c. mains, the *system voltage* is the r.m.s. value of the source a.c. before rectification, taking into account the supply *system* earthing.

NOTE 5 Voltages generated within the *PECS* by the secondaries of transformers providing galvanic isolation from the *mains supply* are also considered to be *system voltages* for the determination of impulse voltages.

See 6.3.7.3 for marking requirements.

4.4.7.1.6.2 For *non-mains supply*

For *PECS* supplied by non-mains a.c. or d.c., the *system voltage* is the r.m.s. value of the supply voltage between phases.

4.4.7.1.7 Components bridging *insulation*

Components bridging *insulation* shall comply with the requirements of the level of *insulation* (e.g. *basic*, *reinforced*, *double*) they are bridging.

4.4.7.2 *Insulation to the surroundings*

4.4.7.2.1 General

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

- the impulse withstand 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, as described in 4.4.7.5.

For clearance distances and solid *insulation*, the impulse withstand voltage, the temporary overvoltage or the recurring peak value of the *working voltage* is used, as described in 4.4.7.2.2 to 4.4.7.2.4.

NOTE 1 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. For more information see A.6.

NOTE 2 The impulse withstand voltage and *temporary overvoltage* depend on the *system voltage* of the circuit, and the impulse withstand voltage also depends on the overvoltage category, as shown in Table 9.

For *PEC* with galvanic isolation between the *mains* and *non-mains* circuits, the impulse voltage withstand ratings of the *mains* and *non-mains* circuits are determined as in 4.4.7.2.2 and 4.4.7.2.3. Thereafter the effect of reduction of the overvoltage categories (OVC) across the isolation is evaluated as follows:

- The magnitude of impulses from the *mains supply* circuit on the *non-mains supply* circuit is determined by reducing the OVC of the *non-mains supply* supplies by one level, and determining the resulting impulse voltage withstand rating based on *mains supply system voltage*.
- The rating to be used on the *non-mains* circuit is the higher of the value in 4.4.7.2.3 and the value determined above.
- The magnitude of impulses from the *non-mains* circuit on the *mains* circuit is determined by reducing the OVC of the *non-mains* circuit by one level, and determining the resulting impulse voltage withstand rating based on *non-mains supply system voltage*.
- The rating to be used on the *mains* circuit is the higher of the value in 4.4.7.2.2 and the value determined above.

For *PEC* not providing galvanic isolation between the *mains* and *non-mains* circuits, the impulse withstand voltage ratings of the *mains* and *non-mains* circuits are determined as

4.4.7.2.2 and 4.4.7.2.3 above. The higher of the two impulse withstand voltage ratings is used for the entire combined circuit. For circuits connected to the combined circuit without galvanic isolation, the impulse withstand voltage rating of the combined circuit applies.

NOTE 3 See I.5 for examples.

When circuits of *DVC A* or *B* are supplied from the mains through a transformer providing galvanic isolation working at a frequency higher than that of the supply, the *insulation* between the circuit and the surroundings may be determined according to the *working voltage* of the circuit.

In that case the transformers ability to reduce the impulse voltages to values less than the impulse voltage associated with the *working voltage* determined from Table 10 shall be shown by test, simulation or calculation.

NOTE 4 The ability of a high frequency transformer to reduce impulse voltages originates from the very low coupling capacitance across the galvanic *insulation* compared to a the typical grounding capacitance in the *DVC A* or *B* circuit.

4.4.7.2.2 Circuits connected to *mains supply*

Insulation between the surroundings and circuits which are connected directly to the *mains supply* shall be designed according to the impulse withstand voltage, *temporary overvoltage*, or *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 *PECS* is connected at the origin of the *installation*. Overvoltage category II may be used for plug-in equipment without special requirements with regard to reliability.

If measures are provided which reduce impulses of overvoltage 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. The requirements for *double* or *reinforced insulation* shall not be reduced to values less than those required for *basic insulation* designed to withstand impulses without these measures being present.

If the devices used for this purpose can be damaged by overvoltages or repeated impulses, thus decreasing their ability to reduce impulses, they shall be monitored and an indication of their status provided.

NOTE 1 The determined impulse withstand voltage based on the *system voltage* may be reduced by means of inherent protection or *SPD* internal in the *PECS* or as part of the *installation*. IEC 61643-12 provides information on the selection and use of such *SPD*.

NOTE 2 Circuits which are connected to the supply mains via *protective impedances*, according to 4.4.5.4, are not regarded as connected directly to the supply mains.

4.4.7.2.3 Circuits connected to *non-mains supply*

Insulation between the surroundings and circuits supplied from a *non-mains supply* shall be designed according to:

- the impulse withstand voltage determined from Table 9 using the *system voltage*;
- the *working voltage*;
- the *temporary overvoltage* if known to exist due to the nature of the supply;

whichever gives the more severe requirement.

These values are used to enter Table 10 for the design of clearance.

Temporary overvoltage on a *non-mains supply* shall be determined as follows: