

AS IEC 62477.1:2024
IEC 62477-1:2022
IEC 62477-1:2022/COR1:2024



STANDARDS
Australia



Safety requirements for power electronic converter systems and equipment

Part 1: General



AS IEC 62477.1:2024

This Australian Standard® was prepared by EL-027, Power Electronics. It was approved on behalf of Standards Australia's Standards Development and Accreditation Committee on 12 June 2024.

This Standard was published on 28 June 2024.

The following are represented on Committee EL-027:

- Australian Industry Group
- Bureau of Steel Manufacturers of Australia
- Department of Defence (Australian Government)
- Energy Networks Australia
- Engineers Australia
- University of Newcastle

This Standard was issued in draft form for comment as DR AS IEC 62477.1:2024.

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ISBN 978 1 76139 697 7

Safety requirements for power electronic converter systems and equipment

Part 1: General

Originated as AS IEC 62477.1:2016.
Second edition 2024.



Standards Australia Ltd 2024

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Preface

This Standard was prepared by the Standards Australia Committee EL-027, Power Electronics, to supersede AS IEC 62477.1:2016.

The objective of this document is to specify requirements for power electronic converter systems (PECS), any specified accessories, and 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 AC or 1 500 V DC.

This document also applies to PECS which intentionally emit or receive radio waves for the purpose of radio communication.

This document can also be used as a reference standard for product committees producing product standards for —

- (a) adjustable speed electric power drive systems (PDS);
- (b) standalone uninterruptible power systems (UPS);
- (c) low voltage stabilized DC power supplies; and
- (d) bidirectional power converters.

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The terms “normative” and “informative” are used in Standards to define the application of the appendices or annexes to which they apply. A “normative” appendix or annex is an integral part of a Standard, whereas an “informative” appendix or annex is only for information and guidance.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**SAFETY REQUIREMENTS FOR POWER ELECTRONIC
CONVERTER SYSTEMS AND EQUIPMENT –****Part 1: General****FOREWORD**

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IEC 62477-1 has been prepared by IEC technical committee 22: Power electronic systems and equipment. It is an International Standard.

This document is developed according to the intent of ISO/IEC Guide 51 and IEC Guide 116.

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

This second edition cancels and replaces the first edition published in 2012 and Amendment 1:2016. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) PECS emitting or receiving radio waves added in the Scope;
- b) simplification of the concept of DVC As including the voltage-time-zones;

- c) improved consistency of the concept "protection" versus "insulation" according to IEC 61140;
- d) limits for touch current updated and limits for PE conductor currents added;
- e) thin sheet of tape materials reworked and tests added;
- f) inner layers of multi-layer printed wiring boards added;
- g) mechanical hazards updated;
- h) requirements for enclosures updated;
- i) requirements for wiring and connections updated;
- j) polymeric enclosure requirements updated;
- k) requirements for components added;
- l) several test added (e.g. UV, working voltage, SPD, preconditioning);
- m) information and marking requirements updated;
- n) requirements for the contrast of symbols added;
- o) several annexes updated.

The text of this International Standard is based on the following documents:

Draft	Report on voting
22/355/FDIS	22/356/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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

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

NOTE Due to the requirement in ISO/IEC Directive Part 2, the defined term is in singular. In this document, also the plural is in *italic*.

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

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

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This document relates to products that include *power electronic converters*, with a rated *system voltage* not exceeding 1 000 V AC or 1 500 V DC. It specifies requirements to reduce risks of fire, electric shock, thermal, energy and mechanical hazards, except functional safety as defined in IEC 61508 (all parts). 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.

During the update of the document, feedback from technical committees which used the IEC 62477-1 as reference document has been taken into consideration.

Modifications have been made to 4.4.2 and Annex A considering the safe to touch voltage *DVC As* under normal operating conditions and *single fault conditions*. On request from TCs using this document as a reference document, the determination of *DVC As* has been simplified. The determination of *DVC As* in IEC 62477-1:2012 and IEC 62477-1:2012/AMD1:2016 was developed based on IEC TS 60479-1:2005¹ and IEC TR 60479-5:2007 and in details taking different environmental condition, size of body contact area and body reaction into consideration. This change also included time-voltage zones in Annex A for relevant body reactions, environmental conditions and contact area.

NOTE See IEC 60479-1:2018 for further information about effects of current on human beings and livestock.

This document follows the simplified concepts of the basic safety standard IEC 61140:2016, 5.2.6, considering two situations in Table 2 of this document:

- a) dry and large contact areas;
- b) all other cases.

For the temporary increase of voltage during *single fault conditions*, it was decided to use the more simplified approach to limit the voltage to the maximum voltage of *DVC B* which is also used by other committees.

This document 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 62103² 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 and electromagnetic compatibility aspects, which are not covered by this document.

- 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.

¹ This publication has been withdrawn.

² This publication has been withdrawn.

This group safety standard will not take precedence over 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)*, any specified *accessories*, and 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 AC or 1 500 V DC.

This document also applies to *PECS* which intentionally emit or receive radio waves for the purpose of radio communication.

This document can 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 DC power supplies;
- bidirectional power converters.

For *PECS* and their specified *accessories* for which no product standard exists, this document provides minimum requirements for safety aspects.

This document has the status of a group safety publication in accordance with IEC Guide 104 for *power electronic converter systems* 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.

Guidance for use of this group safety publication for product committees is given in Annex S.

This document

- establishes a common terminology for safety aspects relating to *PECS*,
- 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 *PECS* portion of products that contain *PECS*,
- 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, and
- specifies minimum requirements to reduce risks with respect to *PECS* designed as pluggable and *permanently connected equipment*, whether it consists of a system of interconnected units or independent units, subject to installing, operating and maintaining the *PECS* in the manner prescribed by the manufacturer.

This document does not cover

- telecommunications apparatus other than power supplies to such apparatus,
- functional safety aspects as covered by, for example, IEC 61508 (all parts), and
- electrical equipment and systems for railways applications and electric vehicles.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60050-112, *International Electrotechnical Vocabulary (IEV) – Part 112: Quantities and units* (available at www.electropedia.org)

IEC 60050-113, *International Electrotechnical Vocabulary (IEV) – Part 113: Physics for electrotechnology* (available at www.electropedia.org)

IEC 60050-114, *International Electrotechnical Vocabulary (IEV) – Part 114: Electrochemistry* (available at www.electropedia.org)

IEC 60050-151, *International Electrotechnical Vocabulary (IEV) – Part 151: Electrical and magnetic devices* (available at www.electropedia.org)

IEC 60050-161, *International Electrotechnical Vocabulary (IEV) – Part 161: Electromagnetic compatibility* (available at www.electropedia.org)

IEC 60050-192, *International Electrotechnical Vocabulary (IEV) – Part 192: Dependability* (available at www.electropedia.org)

IEC 60050-426, *International Electrotechnical Vocabulary (IEV) – Part 426: Explosive atmospheres* (available at www.electropedia.org)

IEC 60050-441, *International Electrotechnical Vocabulary (IEV) – Part 441: Switchgear, controlgear and fuses* (available at www.electropedia.org)

IEC 60050-442, *International Electrotechnical Vocabulary (IEV) – Part 442: Electrical accessories* (available at www.electropedia.org)

IEC 60050-551, *International Electrotechnical Vocabulary (IEV) – Part 551: Power electronics* (available at www.electropedia.org)

IEC 60050-601, *International Electrotechnical Vocabulary (IEV) – Part 601: Generation, transmission and distribution of electricity – General* (available at www.electropedia.org)

IEC 60050-826, *International Electrotechnical Vocabulary (IEV) – Part 826: Electrical installations* (available at www.electropedia.org)

IEC 60068-2-2:2007, *Environmental testing – Part 2-2: Tests – Test B: Dry heat*

IEC 60068-2-6:2007, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-52:2017, *Environmental testing – Part 2-52: Tests – Test Kb: Salt mist, cyclic (sodium chloride solution)*

IEC 60068-2-68:1994, *Environmental testing – Part 2-68: Tests – Test L: Dust and sand*

IEC 60068-2-78:2012, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60320 (all parts), *Appliance couplers for household and similar general purposes*

IEC 60364 (all parts). *Low-voltage electrical installations*

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

IEC 60364-4-41:2005/AMD1:2017

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

IEC 60364-5-54:2011/AMD1:2021

IEC 60384-14:2013, *Fixed capacitors for use in electronic equipment – Part 14: Sectional specification – Fixed capacitors for electromagnetic interference suppression and connection to the supply mains*

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

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

IEC 60529:1989/AMD1:1999

IEC 60529:1989/AMD2:2013

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

IEC 60664-1:2020, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60664-3:2016, *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 60695-2-10:2013, *Fire hazard testing – Part 2-10: Glowing/hot-wire based test methods – Glow-wire apparatus and common test procedure*

IEC 60695-2-11:2021, *Fire hazard testing – Part 2-11: Glowing/hot-wire based test methods – Glow-wire flammability test method for end-products (GWEPT)*

IEC 60695-2-13:2010, *Fire hazard testing – Part 2-13: Glowing/hot-wire based test methods – Glow-wire ignition temperature (GWIT) test method for materials*

IEC 60695-2-13:2010/AMD1:2014

IEC 60695-10-2:2014, *Fire hazard testing – Part 10-2: Abnormal heat – Ball pressure test*

IEC 60695-11-20:2015, *Fire hazard testing – Part 11-20: Test flames – 500 W flame test methods*

IEC 60721-3-3:1994, *Classification of environmental conditions – Part 3-3: Classification of groups of environmental parameters and their severities – Stationary use at weatherprotected locations*

IEC 60721-3-3:1994/AMD1:1995

IEC 60721-3-3:1994/AMD2:1996

IEC 60721-3-4:1995, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Stationary use at non-weatherprotected locations*

IEC 60721-3-4:1995/AMD1:1996

IEC 60730-1:2013, *Automatic electrical controls – Part 1: General requirements*

IEC 60730-1:2013/AMD1:2015

IEC 60730-1:2013/AMD2:2020

IEC 60738-1-1:2008, *Thermistors – Directly heated positive step-function temperature coefficient – Part 1-1: Blank detail specification – Current limiting application – Assessment level EZ*

IEC 60755:2017, *General safety requirements for residual current operated protective devices*

IEC 60799:2018, *Electrical accessories – Cord sets and interconnection cord sets*

IEC 60947-7 (all parts), *Low-voltage switchgear and controlgear – Part 7: Ancillary equipment*

IEC 60949:1988, *Calculation of thermally permissible short-circuit currents, taking into account non-adiabatic heating effects*

IEC 60949:1988/AMD1:2008

IEC 60990:2016, *Methods of measurement of touch current and protective conductor current*

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

IEC 61180:2016, *High-voltage test techniques for low-voltage equipment – Definitions, test and procedure requirements, test equipment*

IEC 61189-3:2007, *Test methods for electrical materials, printed boards and other interconnection structures and assemblies – Part 3: Test methods for interconnection structures (printed boards)*

IEC 61204-7:2016, *Low-voltage switch mode power supplies – Part 7: Safety requirements*

IEC 61558-1:2017, *Safety of transformers, reactors, power supply units and combinations thereof – Part 1: General requirements and tests*

IEC 62109-1:2010, *Safety of power converters for use in photovoltaic power systems – Part 1: General requirements*

ISO/IEC Guide 51:2014, *Safety aspects – Guidelines for their inclusion in standards*

IEC Guide 104:2019, *The preparation of safety publications and the use of basic safety publications and group safety publications*

IEC Guide 116:2018, *Guidelines for safety related risk assessment and risk reduction for low voltage equipment*

ISO 3746:2010, *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 3864 (all parts), *Graphical symbols – Safety colours and safety signs*

ISO 3864-1:2011, *Graphical symbols – Safety colours and safety signs – Part 1: Design principles for safety signs and safety markings*

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

ISO 7010, *Graphical symbols – Safety colours and safety signs – Registered safety signs* (available at <https://www.iso.org/obp>)

ISO 9614-1:1993, *Acoustics – Determination of sound power levels of noise sources using sound intensity – Part 1: Measurement at discrete points*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-112:2010, IEC 60050-113:2011, IEC 60050-114:2014, IEC 60050-426:2020, IEC 60050-151:2001, IEC 60050-161:1990, IEC 60050-192:2015, IEC 60050-441:1984, IEC 60050-442:1998, IEC 60050-551:1998, IEC 60050-601:1985, IEC 60050-826:2004, IEC 60664-1:2020, 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
abnormal operating condition abnormal operation	3.1	fire enclosure	3.29	power semiconductor device	3.57
accessible	3.2	functional insulation	3.30	prospective short-circuit current (I_{cp})	3.58
accessory	3.3	hand-held equipment	3.31	protective equipotential bonding	3.59
adjacent circuit	3.4	hazardous live part	3.32	protective impedance	3.60
basic insulation	3.5	installation	3.33	electrically protective screening protective screening	3.61
basic protection	3.6	impulse withstand voltage	3.34	reinforced insulation	3.62
class I equipment	3.7	live part	3.35	restricted access area	3.63
class II equipment	3.8	low voltage (LV)	3.36	routine test	3.64
class III equipment	3.9	mains supply	3.37	sample test	3.65
clearance	3.10	minimum required prospective short-circuit current ($I_{cp,mr}$)	3.38	service access area	3.66
commissioning test	3.11	movable equipment	3.39	short-circuit backup protection	3.67
component	3.12	non-mains supply	3.40	short-circuit protective device (SCPD)	3.68

Term	Term number	Term	Term number	Term	Term number
conditional short-circuit current (I_{cc})	3.13	open type PECS	3.41	short-time withstand current (I_{cw})	3.69
creepage distance	3.14	general access area	3.42	single fault condition	3.70
decisive voltage class (DVC)	3.15	ordinary person	3.43	skilled person	3.71
de-energized	3.16	output short-circuit current	3.44	solid insulation	3.72
double insulation	3.17	overcurrent protective device (OCPD)	3.45	supplementary insulation	3.73
direct plug-in equipment	3.18	overvoltage category (OVC)	3.46	surge protective device (SPD)	3.74
DVC As	3.19	PE	3.47	system	3.75
DVC B	3.20	peak withstand current (I_{pk})	3.48	system voltage	3.76
DVC C	3.21	PE conductor	3.49	temporary overvoltage	3.77
electric breakdown	3.22	permanently connected equipment	3.50	touch current	3.78
electrical insulation insulation	3.23	pluggable equipment type A	3.51	type test	3.79
electronic power conversion	3.24	pluggable equipment type B	3.52	ventricular fibrillation	3.80
enclosure	3.25	pollution degree	3.53	visual inspection	3.81
enhanced protection	3.26	port	3.54	working voltage	3.82
fault protection	3.27	power electronic converter (PEC)	3.55	zone of equipotential bonding	3.83
field wiring terminal	3.28	power electronic converter system (PECS)	3.56		

3.1

abnormal operating condition

abnormal operation

temporary operating condition that is not a normal operating condition and is not a *single fault condition* of the equipment itself

Note 1 to entry: An *abnormal operating condition* may be introduced by the equipment or by a person and may result in a failure of a *component*, a device or *insulation*.

[SOURCE: IEC 62368-1:2018, 3.3.7.1, modified – Note 1 to entry has been removed, and Notes 2 and 3 to entry have been grouped and rephrased.]

3.2

accessible

able to be touched by means of the standard test finger

Note 1 to entry: For standard test finger, refer to Figure M.2.

Note 2 to entry: The term "accessible" is used to refer to an accessible circuit, an accessible connection, an accessible part or an accessible surface.

3.3

accessory

additional part, component or equipment intended to expand capabilities and/or functionality of the *PECS*

Note 1 to entry: Some examples are:

- external filter,
- communication, control or input/output interface kits,
- external SPD for reduction of transient.
- additional enclosure parts or kits,
- additional ventilation kits,
- mechanical bonding or cable support kits, or
- additional measuring device, instrument etc.

Note 2 to entry: Expanded capabilities is considered to be electrical, mechanical, thermal or acoustic characteristics of the *PECS* when installed and operating as intended.

Note 3 to entry: *Accessories* and *accessory* kits might be factory or field installed.

3.4

adjacent circuit

circuit having a requirement to be protected from the circuit under consideration

3.5

basic insulation

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

[SOURCE: IEC 60050-826:2004, 826-12-14, modified – The definition has been reformulated.]

3.6

basic protection

protection against electric shock under fault-free conditions through the use of *insulation* or distance or a combination of both

Note 1 to entry: For more information, refer to 4.4.3.

[SOURCE: IEC 60050-195:2021, 195-06-01, modified – The words " under fault-free conditions through the use of *insulation* or distance or a combination of both" have been added, as well as the note to entry.]

3.7

class I equipment

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

3.8

class II equipment

PECS in which protection against electric shock does not rely on *basic protection* only, but in which additional safety precautions are provided, there being no means of connection for the *PE conductor* or reliance upon *installation* conditions

Note 1 to entry: *Supplementary insulation* or *reinforced insulation* are additional safety precautions.

3.9**class III equipment**

PECS in which protection against electric shock relies on supply at *DVC* As and in which voltages higher than those of *DVC* As are not generated and there is no means for protective earthing

3.10**clearance**

shortest distance in air between two conductive parts

Note 1 to entry: This distance can be measured along a string stretched the shortest way between these conductive parts.

[SOURCE: IEC 60664-1:2020, 3.1.4, modified – The note to entry has been added.]

3.11**commissioning test**

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

[SOURCE: IEC 60050-411:1996, 411-53-06, modified – The word "machine" has been replaced by "device" and "equipment" with "*PECS*".]

3.12**component**

part of a *PEC* or *PECS*, which cannot be physically divided into smaller parts without losing its particular function

[SOURCE: IEC 60050-151:2001, 151-11-21, modified – The words "constituent part of a device" have been replaced by "part of a *PEC* or *PECS*".]

3.13**conditional short-circuit current**

I_{cc}

RMS value of a *prospective short-circuit current* available from a source, under conditions specified by the *PECS* manufacturer, using a specific type of *short-circuit protective device*

Note 1 to entry: See also Figure N.1.

Note 2 to entry: The source might be a mains supply or non-mains supply.

Note 3 to entry: The declared I_{cc} is the minimum current value used for calibration of the supply source.

3.14**creepage distance**

shortest distance along the surface of a solid insulating material between two conductive parts

[SOURCE: IEC 60664-1:2020, 3.1.5]

3.15**decisive voltage class**

DVC

classification of voltage range used to determine the protective means against electric shock and the requirements of protection between circuits

3.16**de-energized**

free from all potential energy hazards

3.17**double insulation**

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

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

3.18**direct plug-in equipment**

PECS in which the *mains supply* plug forms an integral part of the *PECS enclosure* so that the *PECS* is supported by the *mains supply* socket-outlet

[SOURCE: IEC 60050-903:2014, 903-04-07, modified – "Equipment" replaced by "*PECS*" and "mains" by "mains supply".]

3.19**DVC As**

voltage classification of a circuit providing only safe to touch voltage, under normal operating conditions and *single fault condition*, and limited overvoltages

Note 1 to entry: See 4.4.2.2 and Table 2.

3.20**DVC B**

voltage classification of a *circuit* which stays within the voltage limits between *DVC As* and *DVC B* under normal operating conditions and *single fault conditions*

Note 1 to entry: See 4.4.2.3 and Table 2.

3.21**DVC C**

voltage classification of any circuit not meeting the protection requirements or voltage limits for *DVC B* or *DVC As*

Note 1 to entry: See 4.4.2.4 and Table 2.

3.22**electric 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 60664-1:2020, 3.1.44]

3.23**electrical insulation
insulation**

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

Note 1 to entry: For the protection against electric shock, insulation types like clearance, creepage distances and solid insulation are used as means for basic protection, fault protection and enhanced protection. Further means for basic protection, fault protection and enhanced protection are specified in 4.4.3, 4.4.4 and 4.4.5.

3.24**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 – The words "electronic valve devices" have been replaced by "*power semiconductor devices*".]

3.25 enclosure

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

Note 1 to entry: This document provides requirements for the *enclosure* according to IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013 as well as additional requirements for mechanical and environmental impact. The purpose of the additional requirements is to ensure the ability of an *enclosure* to provide *basic protection* under the environmental conditions specified by the manufacturer.

[SOURCE: IEC 60050-151:2001, 151-13-08, modified – Note 1 to entry has been added.]

3.26 enhanced protection

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

Note 1 to entry: *Enhanced protection* can be realized through the use of insulation or distance or a combination of both. For more information, refer to 4.4.5.

[SOURCE: IEC 61140:2016, 3.19, modified – The words "protective provision" has been replaced by "protection" in the term, and "provision" by "means" in the definition.]

3.27 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 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017, mainly with regard to failure.

Note 2 to entry: For more information, refer to 4.4.4.

[SOURCE: IEC 60050-195:2021, 195-06-02, modified – The notes to entry have been added.]

3.28 field wiring terminal

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

3.29 fire enclosure

part of the *PECS* intended to minimize the spread of fire or flames from within the *enclosure* to outside the *enclosure*

3.30 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.

3.31 hand-held equipment

PECS intended to be held in the hand during normal use

[SOURCE: IEC 60050-195:2004, 826-16-05, modified – The words "electric equipment" have been replaced by "*PECS*".]

3.32**hazardous live part**

live part which can give a harmful electric shock

Note 1 to entry: In this document a *hazardous live part* does not meet the requirements of *DVC* As in 4.4.2.2.

[SOURCE: IEC 60050-195:2021, 195-06-05, modified – The hyphens have been deleted from the term, the words "under certain conditions" have been deleted from the definition and the note to entry added.]

3.33**installation**

equipment including at least the *PECS*

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

3.34**impulse withstand voltage**

highest peak value of impulse voltage of prescribed form and polarity which does not cause breakdown of *insulation* under specified conditions

[SOURCE: IEC 60050-442:2014, 442-09-18]

3.35**live part**

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

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

[SOURCE: IEC 60050-195:2021, 195-02-19, modified – The words "and mid-point conductor, but excluding the PEN conductor, PEM conductor and PEL conductor" have been replaced by "but by convention not a *PE conductor* or *protective earth* neutral".]

3.36**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 AC or 1 500 V DC

[SOURCE: IEC 60050-601:1985, 601-01-26, modified – The words "for alternating current" have been replaced by "AC", and the words "or 1 500 V DC" have been added.]

3.37**mains supply**

low voltage AC or DC power distribution *system* for supplying power to AC or DC *PECS*

Note 1 to entry: In the USA and Canada, the term "*mains supply*" is called "utilities".

3.38**minimum required prospective short-circuit current**

$I_{cp,mr}$

RMS value of a minimum *prospective short-circuit current*, which shall be available from the source to ensure operation of the specific type of *short-circuit protective device*

3.39 movable equipment

PECS that is either

- 18 kg or less in mass and not fixed in place, or
- provided with wheels, casters, or other means to facilitate movement by an *ordinary person* as required to perform its intended use

3.40 non-mains supply

low voltage AC or DC power network that is not energized directly from the *AC mains supply* or *DC mains supply*

Note 1 to entry: Examples of *non-mains supplies* are those which are isolated by a transformer or supplied by a battery, generator, solar arrays, wind generator, tidal *systems*, wave, fuel cell or similar sources not directly connected to the AC or DC power distribution *system*.

3.41 open type PECS

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

3.42 general access area

area of the *PECS* to which both *ordinary persons* and *skilled persons* are permitted access

Note 1 to entry: *General access areas* do not require the use of a tool or key.

3.43 ordinary person

person who is not a *skilled person*

Note 1 to entry: *Ordinary person* is the term applied to all persons other than *skilled persons*. *Ordinary persons* include not only users of the equipment, but also all persons who may have access to the equipment or who may be in the adjacency of the equipment. Under normal operating conditions or *abnormal operating conditions*, *ordinary persons* should not be exposed to parts comprising energy sources capable of causing pain or injury. Under a *single fault condition*, *ordinary persons* should not be exposed to parts comprising energy sources capable of causing injury.

Note 2 to entry: Instructed person is not used in this document.

[SOURCE: IEC 60050-826:2004, 826-18-03, modified – Instructed person deleted, notes to entry added.]

3.44 output short-circuit current

available current that flows at the output *port* of the *PECS* when a short-circuit is applied

3.45 overcurrent protective device

OCPD

device provided to interrupt an electric circuit in case the current in the electric circuit exceeds a predetermined value for a specified duration

[SOURCE: IEC 60050-826:2004, 826-14-14, modified – The abbreviated term "OCPD" has been added, and the word "conductor" have been deleted from "conductor current".]

3.46 overvoltage category

OVC

numeral defining a transient overvoltage condition

Note 1 to entry: *Overvoltage categories* I, II, III and IV are used. See 4.4.7.1.4 for information.

[SOURCE: IEC 60664-1:2020, 3.1.20, modified – The abbreviated term "OVC" has been added, and the reference has been updated in the note to entry.]

3.47

PE

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

Note 1 to entry: In the USA and Canada, the term "ground" is used instead of "earth".

3.48

peak withstand current

I_{pk}

value of peak short-circuit current, declared by the *PECS* manufacturer, which can flow under specified conditions

Note 1 to entry: For the purpose of this document, I_{pk} refers to the initial asymmetric peak value of the prospective test current.

[SOURCE: IEC 61439-1:2020, 3.8.10.2, modified – The definition is modified for *PECS* application.]

3.49

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

3.50

permanently connected equipment

PECS that can only be connected to or disconnected from the electric power system by the use of a tool

Note 1 to entry: In this document, electric power system is considered as either *mains supply* or *non-mains supply*.

[SOURCE: IEC 60050-151:2014, 151-11-29, modified – "Equipment" replaced by "*PECS*" and note to entry added.]

3.51

pluggable equipment type A

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

Note 1 to entry: For non-industrial plug and socket-outlets, see IEC TR 60083:2015 or a national equivalent. For non-industrial appliance couplers, see IEC 60320-1.

[SOURCE: IEC 60050-903:2014, 903-04-08, modified – The word "equipment" has been replaced by "*PECS*" and "mains" by "*mains supply*".]

3.52

pluggable equipment type B

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

Note 1 to entry: For industrial plug and socket-outlets, see IEC 60309-1 or a national equivalent. For non-industrial appliance couplers, see IEC 60320-1.

[SOURCE: IEC 60050-903:2014, 903-04-09, modified – The word "equipment" has been replaced by "*PECS*" and "mains" by "*mains supply*".]

3.53**pollution degree**

numeral characterizing the expected pollution of the micro-environment.

Note 1 to entry: Pollution degrees 1, 2, 3 and 4 are used in this document. See 4.4.7.1.3 for information.

[SOURCE: IEC 60664-1:2020, 3.1.25, modified – Note to entry added.]

3.54**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, modified – The note has been deleted.]

3.55**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

3.56**power electronic converter system****PECS**

system consisting of *power electronic converter(s)* intended to work together with other equipment

3.57**power semiconductor device**

semiconductor device used for *electronic power conversion*

3.58**prospective short-circuit current**

I_{cp}

RMS value of the current which would flow if the supply conductors to the circuit are short-circuited by a conductor of negligible impedance located as near as practicable to the supply terminals of the *PECS*

[SOURCE: IEC 61439-1:2020, 3.8.7, modified – The word "current" has been replaced by "RMS value of the current", and "assembly" by "*PECS*" and Note to entry deleted.]

3.59**protective equipotential bonding**

equipotential bonding for the purposes of safety

EXAMPLE Protection against electric shock

[SOURCE: IEC 60050-195:2021, 195-01-15, modified – The hyphens have been removed from the term, and the example has been added.]

3.60**protective impedance**

impedance connected between *hazardous live parts* and conductive *accessible parts*, of such value that the current, in intended use and under *single fault conditions*, is limited to a safe value, and which is so constructed that its ability is maintained throughout the life of the *PECS*

3.61
electrically protective screening
protective screening

separation of electric circuits and/or conductors from *hazardous live parts* by an electrically protective screen connected to the *protective equipotential bonding system* and intended to provide protection against electric shock

[SOURCE: IEC 60050-195:2021, 195-06-18, modified – The word "electrically" has been added to "protective screening", and the term "protective shielding" has been deleted.]

3.62
reinforced insulation

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

Note 1 to entry: *Reinforced insulation* may comprise several layers which cannot be tested separately as *basic insulation* or *supplementary insulation*.

[SOURCE: IEC 60664-1:2020, 3.1.33]

3.63
restricted access area

area to which only electrically skilled persons with the proper authorization have access

[SOURCE: IEC 60050-195:2021, 195-04-04, modified – The words "and electrically instructed persons" have been removed.]

3.64
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 – The word "machine" has been replaced by "device".]

3.65
sample test

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

3.66
service access area

enclosed electrical area intended for service, maintenance and commissioning while the *PECS* is energized and to which only *skilled persons* are permitted access

Note 1 to entry: *Service access areas* require the use of a tool or key.

3.67
short-circuit backup protection

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

3.68
short-circuit protective device

SCPD

device intended to protect a circuit or parts of a circuit against short-circuit currents by interrupting them

Note 1 to entry: A *short-circuit protective device* is suitable for protection against short-circuit only, not for protection against overload. An *OCPD* may also incorporate the function of a *SCPD*.

[SOURCE: IEC 61439-1:2020, 3.1.11, modified – The note to entry has been added.]

3.69 short-time withstand current

I_{cw}

RMS value of short-time current, declared by the *PECS* manufacturer, which can flow under specified conditions, defined in terms of current and time

[SOURCE: IEC 61439-1:2020, 3.8.10.3, modified – The word "rated" has been removed from the term, the words "AC or mean value of DC" have been removed from the definition, "assembly" has been replaced by "*PECS*", and "that can be withstood" by "which can flow".]

3.70 single fault condition

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

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, sound pressure etc.

3.71 skilled person

person with relevant education and experience to enable him or her to perceive risks and to avoid hazards which the equipment can create

Note 1 to entry: *Skilled person* is a term applied to persons who have training or experience in the equipment technology, particularly in knowing the various energies and energy magnitudes used in the equipment. *Skilled persons* are expected to use their training and experience to recognize energy sources capable of causing pain or injury and to take action for protection from injury from those energies. *Skilled persons* should also be protected against unintentional contact or exposure to energy sources capable of causing injury.

Note 2 to entry: It has not been considered necessary to differentiate between the safety means applicable for *skilled persons* and instructed (trained) persons as defined in IEC 61140:2016. The same safety means apply for both.

[SOURCE: IEC 60050-826:2004, 826-18-01, modified – The adverb "electrically" has been removed from the term, the word "electricity" has been replaced by "the equipment", and the note to entry has been added.]

3.72 solid insulation

solid insulating material or a combination of solid insulating materials, placed between two conductive parts or between a conductive part and a body part

[SOURCE: IEC 60664-1:2020, 3.1.6]

3.73 supplementary insulation

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

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

[SOURCE: IEC 60664-1: 2020, 3.1.31, modified – The note to entry has been added.]

3.74**surge protective device****SPD**

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

[SOURCE: IEC 61643-11:2011, 3.1.1, modified – The note to entry has been removed.]

3.75**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.

3.76**system voltage**

voltage used to determine *insulation* requirements

Note 1 to entry: See 4.4.7.1.7 for further consideration of *system voltage*.

3.77**temporary overvoltage**

overvoltage at power frequency of relatively long duration

[SOURCE: IEC 60664-1:2020, 3.1.12]

3.78**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]

3.79**type test**

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

3.80**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]

3.81**visual inspection**

scrutiny by eye of an item carried out either without dismantling, or with the addition of partial dismantling as required in order to arrive at a reliable conclusion as to the condition of an item

[SOURCE: IEC 60050-426:2020, 426-14-02, modified – The adjective "visual" has been deleted from the term, and the definition has been rephrased.]

3.82**working voltage**

AC or DC voltage, at rated supply conditions (without tolerances) and worst case operating conditions, including RMS, recurring peak and mean values that occurs by design in a circuit or across protection means

3.83**zone of equipotential bonding**

zone where all simultaneously conductive *accessible 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* and specified *accessories* for the intended use, to ensure its safety during installation, normal operating conditions and maintenance for the expected life cycle of the *PECS*. Consideration is also given to minimize hazards resulting from reasonably foreseeable misuse.

Information about the intended use, normal operating conditions and specified *accessories* shall be stated in the documentation.

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

Clause 4 provides safety means for protection against hazards for *ordinary persons*. This document also considers relaxed safety means for *skilled persons* considering installation and maintenance of the *PECS*.

NOTE It has not been considered necessary to differentiate between the safety means applicable for *skilled persons* and instructed persons as defined in IEC 61140:2016. The same safety means apply for both.

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

Risk assessment of the *PECS* might show hazards which are not covered by this document. For information, refer to Annex R.

For marking, see 6.2.

4.2 Single fault conditions and abnormal operating conditions

The *PECS* and specified *accessories* shall be designed to avoid operating modes or sequences that can cause a *single fault condition* or *component* failure leading to a hazard, unless other means to prevent the hazard are provided by the *installation* and are described in the *installation* information provided with the *PECS*, see Clause 6. The requirements in 4.2 also apply to *abnormal operating conditions* as applicable.

An analysis shall be performed to identify potential hazards.

This analysis shall include situations where a *single fault condition* in any *component*, *basic protection*, *fault protection* or *port* would result in:

- electrically induced mechanical force and thermal hazard according to 4.3;

- 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, molten metal or fire according to 4.6;
- a risk of thermal hazard due to high temperature according to 4.6; or
- a risk of mechanical hazard according to 4.7.

NOTE This document does not provide any requirement to protect against chemical hazard.

The analysis and 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 effect of other identified *abnormal operating condition* and *single fault condition* shall be tested according to the applicable test in 5.2.4.

The evaluation of *components* (see 4.13) shall be based on the expected stress occurring in the life cycle 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 4.4.7.1 (expected impulse voltage, *working voltage*, *temporary overvoltage*, etc.); or
- micro-environment according to 4.4.7 (*pollution degree*, humidity, etc.).

Components evaluated according to relevant product standards in 4.13 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* for *supplementary insulation*, *double insulation* 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 printed wiring boards (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 6.3.9.6) taking into account the automatic disconnection of supply in 4.4.4.4.

To ensure proper coordination with *short-circuit protective devices (SCPD)* and the available *prospective short-circuit current*, the *PECS* manufacturer shall specify and test for each *mains supply port* of the *PECS*:

- *conditional short-circuit current* (I_{cc}) according to 4.3.2.2; or
- *short-time withstand current* (I_{cw}) according to 4.3.2.3.

Individual *mains supply ports* of a *PECS* shall have specific short-circuit ratings of either I_{cc} or I_{cw} , or of both.

Only in case where compliance does not rely on the current limiting characteristic of *SCPD*, the I_{cw} in 4.3.2.3 can apply.

In case an output *port* is connected or intended to be connected to the input *mains supply port*, the output *port* shall also be specified with an I_{cc} or I_{cw} rating (e.g. bypass between input *mains supply port* and output *port*).

For marking, see 6.2.1.

See Annex N for further information.

Protective *systems* or devices shall be provided or specified in sufficient quantity and location so as to detect and/or interrupt or limit the current flowing in any possible fault current path, caused by any internal or external faults.

NOTE 1 In this document, 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*.

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

No protection is required against overcurrent to earth on *ports* 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 4.4.7.1.5) 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 *PECS* designed as *pluggable equipment type A*, the protective device is provided in the *installation* and shall not require any specific characteristics other than that required in local *installation* codes.

For *PECS* designed as *pluggable equipment type B* or *permanently connected equipment*, this protection may be provided by devices external to the *PECS*, in which case the documentation 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 6.3.9.6).

NOTE 5 IEC 60364 (all parts) 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 (all parts) 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 are interrupted.

For *PECS* that can not deliver *short-circuit currents* which are able to open *SCPD*, the output short-circuit test 5.2.4.4 may be omitted.

Compliance shall be checked by analysis of *single fault conditions* according to 4.2 and by the tests of 5.2.4.4 and 5.2.4.5.

4.3.2 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* or *non-mains supply*.

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 the result of one test is representative of the worst case, less severe combinations need not be tested.

4.3.2.2 Conditional short-circuit current (I_{cc}) on input ports

In case where the *PECS* manufacturer selects the conditional short-circuit current (I_{cc}) rating according to 4.3.1, the following shall be specified:

- *conditional short-circuit current* (I_{cc});
- characteristics of the *short-circuit protective device*; and
- *minimum required prospective short-circuit current* ($I_{cp,mr}$).

Compliance is shown through evaluation according to 4.2, to determine the appropriate combination of testing according to 5.2.4.4, 5.2.4.6 and 5.2.3.11.3 in order to evaluate *single fault conditions* and *abnormal operating conditions*.

4.3.2.3 Short-time withstand current (I_{cw}) on input ports

When the *PECS* manufacturer selects the *short-time withstand current* (I_{cw}) rating according to 4.3.1, the following shall be specified:

- *short-time withstand current* (I_{cw});
- associated duration; and
- *peak withstand current* (I_{pk}).

Compliance is shown through evaluation according to 4.2 to determine the appropriate combination of testing according to 5.2.3.11.3 and 5.2.4.4.3 in order to evaluate *single fault conditions* and *abnormal operating conditions*.

4.3.2.4 Output short-circuit current ability

The ability of the *PECS* to deliver a current, in the event of a short-circuit at the output, shall be defined in amperes and time.

NOTE The specification of current and time is to ensure sufficient information selecting the protective downstream device for the final application.

Compliance is verified by test in 5.2.4.4.

For marking, refer to 6.2.

4.3.2.5 Combined input and output ports

For *ports* which are both input and output *ports*, the applicable requirements of both 4.3.2.1 and 4.3.2.4 apply.

4.3.3 Short-circuit coordination (backup protection)

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

For *PECS* designed as *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 *PECS*.

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

If internal protection of the *PECS* is not rated for the *prospective short-circuit current*, the documentation shall specify an upstream protective device, rated for this *prospective short-circuit current* of that *port*. Analysis shall ensure the protection coordination so that the external protection opens before the internal protection.

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 *visual inspection* in 5.2.1 and simulation or by the tests of 5.2.4.4 and 5.2.4.5.

For marking, refer to 6.3.9.6.

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 *visual inspection* in 5.2.1.

For marking, see 6.5.6.

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 protection requirements from 4.4.2.7 and shall be provided by at least one of the following means:

- *basic protection* from 4.4.3 in combination with *fault protection* from 4.4.4; or
- *enhanced protection* from 4.4.5.

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

Enhanced protection provides protection under both normal operating conditions and *single fault conditions*.

For the use of means of *basic protection* in combination with *fault protection* and *enhanced protection*, see 4.4.6 for different constructions.

Basic protection, *fault protection* and *enhanced protection* may be achieved by means of

- *clearance* and *creepage distances* (4.4.7.4 and 4.4.7.5);
- *solid insulation* (4.4.7.8);
- *protection* by means of *enclosure* and barriers (4.4.3.3); or
- a combination of those means.

Figure 1 and Figure 2 provide an overview of the fundamental concept for protection against electric shock according to IEC 61140:2016.

Where not stated otherwise in this document, protection against electric shock is based on the body reaction *ventricular fibrillation*.

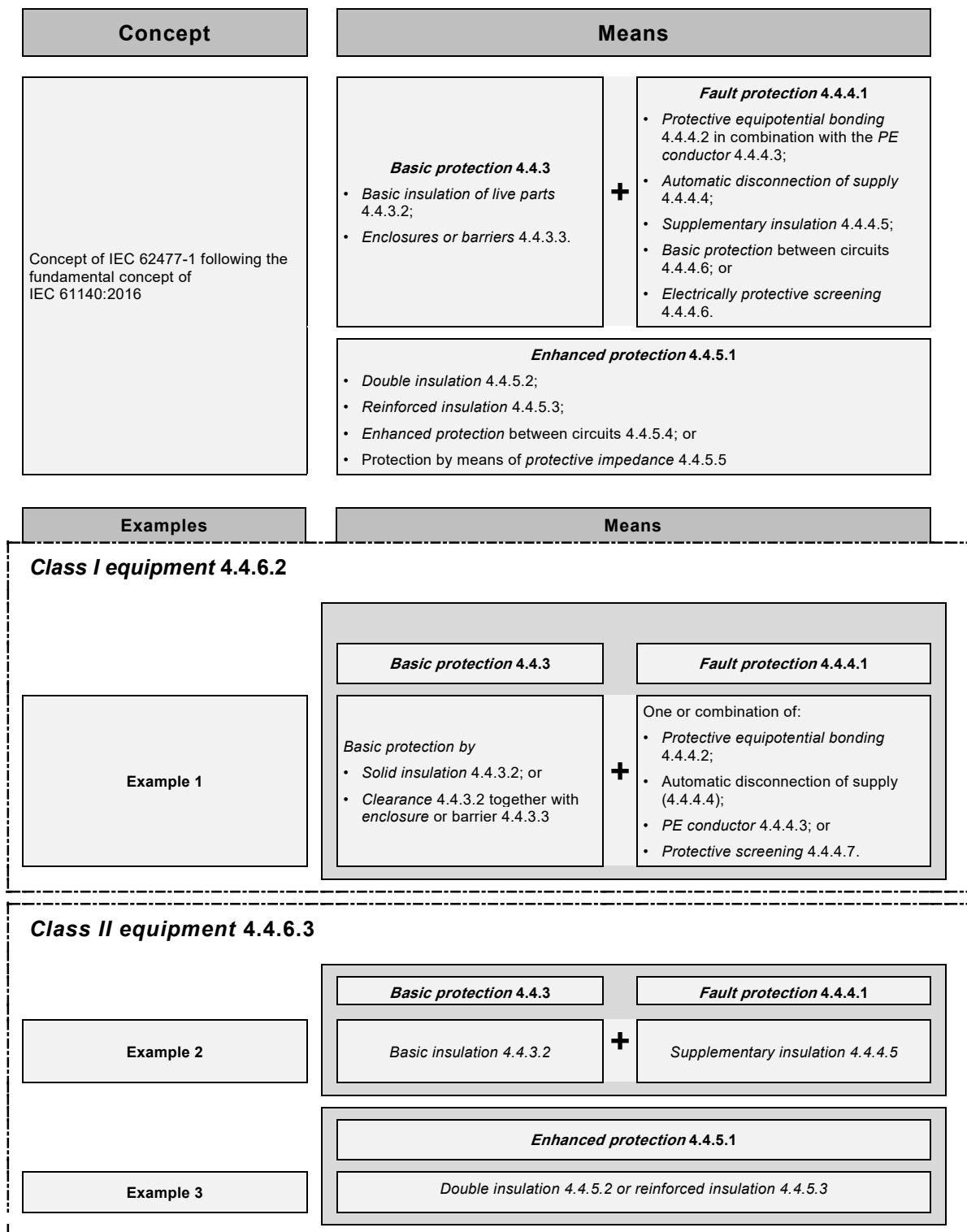


Figure 1 – Protective means for protection against electric shock considering Class I equipment and Class II equipment

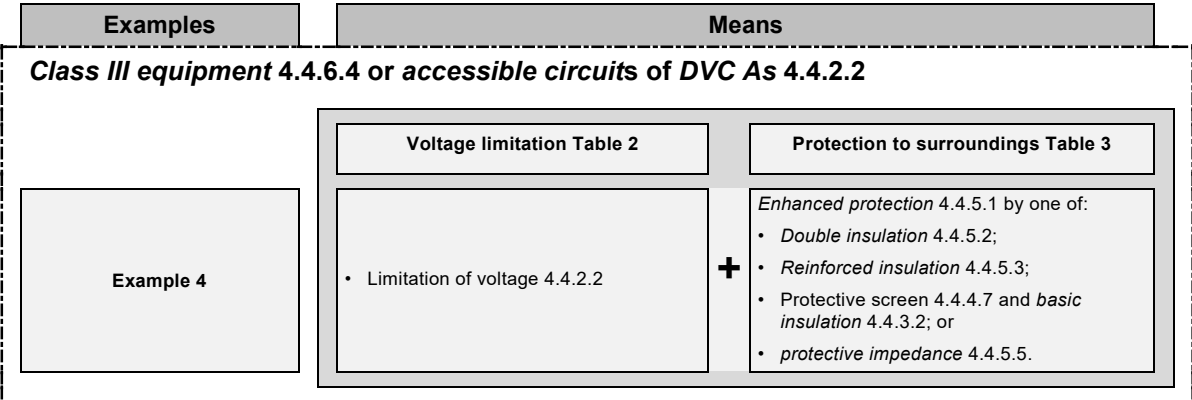


Figure 2 – Protective means for protection against electric shock considering Class III equipment or accessible circuits of DVC As

Additional protection according to IEC 61140:2016 can be provided by residual current-operated protective devices (RCD). For further information, see 4.4.8.

NOTE In this document, 4.4.1 to 4.4.6 have been harmonized with the concepts of the horizontal standard IEC 61140:2016 for protection against electric shock. *Basic protection, fault protection, enhanced protection* and the combination of those means have been implemented.

4.4.2 Decisive voltage class

4.4.2.1 General

This document considers three different types of circuits for the protection against electric shock: *DVC As*, *DVC B* and *DVC C*.

The determination of a *decisive voltage class* includes the following considerations:

- environmental conditions (dry, wet or salt-water-wet) for *DVC As*;
- normal operating conditions and *single fault conditions* for *DVC As*;
- size of body contact surface area for *DVC As*;
- maximum *working voltage* (AC RMS, AC peak and DC) (see Table 2);
- protection requirement between circuits and between circuits and surroundings (see Table 3); and
- *impulse withstand voltage* (see Table 2 and Table 7).

The manufacturer defines the *DVC* for the individual output circuits and provides this information with the documentation (see 6.2).

Input/output circuits with rated voltages within the limits of *DVC As* shall be investigated as *DVC As* circuits. Only circuits which are classified as *DVC As* shall be *accessible* to *ordinary person*.

For marking, see 6.2.1.3.

The probability of electric shock increases with voltage level, surface area of the conductive *accessible 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* for *accessible circuits*, the following apply:

- the reaction of the body (perception, pain, let-go, ventricular fibrillation);
- the area of the *accessible part* of the *PECS* in relation to the area of the part of the body that may contact the *accessible part*; and
- the humidity condition of the body skin (dry, water-wet, saltwater-wet).

The values in Table 2 are based on a current path from the contact area hand to feet with the person in standing position, unless otherwise noted.

NOTE 1 For further information about body reactions, contact areas and humidity skin condition, see IEC 60479-1:2018.

NOTE 2 The design of a safe to touch *DVC As* circuit is simplified in this document. A more complex approach considering the body reaction, contact area and humidity skin condition as described in IEC 60479-1:2018 for the determination of *DVC As* can be used in a risk assessment (see IEC Guide 116) to show that an equivalent protection against electric shock is achieved.

4.4.2.2 *DVC As*

Under normal operating conditions, *abnormal operating conditions* and *single fault conditions*, the *DVC As* circuit shall meet the minimum requirements of:

- the voltage limits according to Table 2; and
- the protection requirement to the surroundings and *adjacent circuits* according to Table 3.

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

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

4.4.2.3 *DVC B*

DVC B circuit shall meet the requirements of:

- the voltage limits according to Table 2;
- the protection requirement to the surroundings and *adjacent circuits* according to Table 3; and
- an *impulse withstand voltage* according to Table 7 determined by the requirement of 4.4.7.2.4.

4.4.2.4 *DVC C*

DVC C circuit shall meet the requirements of:

- the voltage limits according to Table 2;
- protection of persons and protection to the surroundings and *adjacent circuits* according to Table 3; and
- an *impulse withstand voltage* and *temporary overvoltage* according to Table 7 determined by the requirements of 4.4.7.1 to 4.4.7.4.

The protection requirements to other *DVC C* circuits shall be based on the consequence of a *single fault condition* (see 4.2). The protection shall be based on the highest *working voltage* and *impulse withstand voltage*.

4.4.2.5 Interconnection of external SELV/PELV to *DVC As* circuits

External SELV/PELV circuits intended to be connected to the *PECS* shall be investigated per their rated voltage at the point of interconnection according to *DVC As* or *DVC B* as defined in Table 2.

NOTE For values of SELV/PELV, refer to IEC 61140:2016, 5.2.6.

The *DVC* classification of the external circuits shall ensure that the external voltage does not violate the *DVC As* classification for the *PECS* considering the environmental conditions specified.

For marking, see 6.3.9.1.

4.4.2.6 Determination of the *decisive voltage class (DVC)*

The *decisive voltage class (DVC)* is used to determine the required level of protection from circuits to their surroundings in Table 3. For determination of the *working voltage*, see 4.4.7.1.2.

Examples for determination of the *DVC* are given in Clause A.5.

Limits for the *working voltage* for *DVC* are given in Table 2.

Table 2 – Voltage limits for the *decisive voltage classes DVC*

DVC	Limits of working voltage				
	During normal operation conditions				During single fault conditions and abnormal operating conditions
	V				V
	AC voltage (RMS) U_{AC}	AC voltage (peak) U_{peak}	DC voltage (mean) U_{DC}	Impulse withstand voltage U_{peak}^c	Voltage (AC peak or DC) ^b
DVC As (wet and salt water-wet) ^{d, e}	6	8,5	15	800	see Figure 5 and Figure 6
DVC As ^f (dry)	25 (30)	35,4 (42,4)	60		
DVC B	50	71	120	According to Table 7 ^a	
DVC C	1 000	4 500 ^g	1 500		

^a For *non-mains supply*, see 4.4.7.2.4.

^b Single pulses relate to DC voltage limits and repetitive pulses relate to AC voltage limits.

^c Maximum transients with the 1,2/50 μs impulse characteristic as design criteria. Refer to Table 7.

^d Values are derived from IEC 61140:2016, 5.2.6.

^e For climatic conditions, refer to Table 18.

^f Values in brackets are permitted if only one circuit is provided or circuits are not simultaneously *accessible*.

^g The value of 4 500 V allows all low-voltage products to be covered by this document (possible reflections up to $3 \times \sqrt{2} \times 1\,000\text{ V} = 4\,242\text{ V}$).

Within a time according to Figure 5 and Figure 6, the voltage shall decrease to the steady state value given in Table 2 or the fault shall 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 5, Figure 6 and Figure 7 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 documentation according to 6.3.9.6.

For testing, see 5.2.4.

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

4.4.2.7 Requirements for protection against electric shock

Table 3 shows possible solutions for compliance with 4.4 for the application of *enhanced protection* or *basic protection*, dependent on the *DVC* of the circuit under consideration and of *adjacent circuits*.

The requirements of this document for protection against electric shock may be fulfilled by other means than shown in Table 3, in which case failure analysis according to 4.2 and testing shall show that the requirements of 4.1 and 4.4 are met.

Table 3 – Minimum protection requirements for circuit under consideration

Circuit under consideration	To accessible parts connected to PE ^g	To accessible parts not connected to PE ^a	To adjacent circuit		
			DVC As	DVC B	DVC C
	General access areas	Service access areas or restricted access areas			
	For ordinary persons and skilled persons	For skilled persons ^e			
DVC As	None ^b	None ^b	None ^{b,c,d}	Basic protection ^f	Enhanced protection
DVC B	None ^b	Basic protection	Basic protection ^f	None ^{b,c,d}	Enhanced protection
DVC C	Basic protection	Enhanced protection	Enhanced protection	Enhanced protection	None ^{b,d,e}

For more information on *basic protection*, see 4.4.3.

For more information on *enhanced protection*, see 4.4.5.1.

NOTE 1 This table describes the protection requirements between different galvanically separated circuits.

NOTE 2 Refer to Annex A for further explanation.

NOTE 3 For *DVC As*, take into account the level of Table 2.

NOTE 4 See row 4 of Table A.1 for protection requirement for openings in *enclosures*.

^a Any connection not fulfilling 4.4.4.2, for example functionally earthed.

^b Protection is not necessary for safety, but may be required for functional reasons according to 4.4.7.3. For *DVC As* circuits located in different environments, *basic protection* shall be used.

^c *Enhanced protection* is needed, if a *single fault condition* between circuits leads to a violation of the individual circuit's *DVC* classification.

^d *Basic protection* is needed based on the circuit with the higher voltage, if a *single fault condition* between circuits leads to voltages exceeding that of the circuit with the lower voltage.

^e *Enhanced protection* is needed based on the circuit with the higher voltage, if a *single fault condition* between *DVC C* circuits would result in a hazard.

^f *Basic protection* is sufficient, if it can be ensured that the values of *DVC B* are only present for a short period of time according to Figure 5 and Figure 6. Otherwise, *enhanced protection* is required.

^g Any connection fulfilling 4.4.4.2.

^h See 4.4.3.3.

To ensure the integrity of the protection of the *PECS*, the manufacturer of a *PECS* shall state the maximum voltage allowed to be connected to each *port*.

For marking, see 6.3.9.1.

4.4.3 Means for *basic protection* (protection against direct contact)

4.4.3.1 General

4.4.3 describes the means of *basic protection*. To prevent persons from touching *hazardous live parts* under normal operating condition, *basic protection* is employed. It shall be provided by means given below as specified in 4.4.1:

- protection by means of *basic insulation* of *hazardous live parts* in 4.4.3.2; or
- protection by means of *enclosures* or barriers in 4.4.3.3.

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

Basic insulation shall be provided by means of

- *solid insulation*; or
- *clearance* and *creepage distances* in combination with means of *enclosures* or barriers according to 4.4.3.3.

The *insulation* shall be rated according to the *impulse withstand 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.

A conductive *accessible 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 conductive *accessible part* is considered to be a *hazardous live part* if not separated from the *live parts* by at least the minimum protective requirements specified in Table 3.

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

Compliance is shown by test of 5.2.3.2 and 5.2.3.4.

4.4.3.3 Protection by means of *enclosures* or barriers

Hazardous live parts shall be arranged in *enclosures* or located behind *enclosures* or barriers, which meet at least the requirements of IP2X according to IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013.

However, *hazardous live parts* located at the top surfaces of *enclosures* or barriers which are *accessible* when the PECS is energized shall meet at least the requirements of type IP3X with regard to vertical access only.

For PECS designed as *movable equipment* with no defined top and bottom, this requirement of IP3X applies to all sides.

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

Openings in the *enclosure* above 1,8 m shall comply with IPXXB.

Compliance is checked by test of 5.2.2.2.

Opening *enclosures* or removing barriers shall be possible only through:

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

Where the *enclosure* is intended to be opened by *skilled persons* only and the *PECS* is energized during installation or maintenance:

- a) *accessible hazardous live parts* shall be protected by at least IPXXA;
- b) *hazardous live parts* that are likely to be touched when making adjustments shall be protected by at least IPXXB; and
- c) it shall be ensured that persons are aware that *hazardous live parts* are *accessible*, and shall be marked per the requirements in 6.3.9.1 and 6.5.1.

The protective means against access to *hazardous live parts* by means of *enclosure* and barriers according to 4.4.3.3 does not apply to *open type* sub-assemblies and *PECS* intended to be installed

- inside a supplementary *enclosure* in the end application; or
- in a *restricted access area*.

when marked according to 6.3.6.2.

4.4.4 Means for *fault protection* (protection against indirect contact)

4.4.4.1 General

Subclause 4.4.4 describes the means for *fault protection*. *Fault protection* is required to prevent electric shock which can result from contact with conductive *accessible parts* during and after a failure.

The *fault protection* shall be provided by one or more of the following means:

- *protective equipotential bonding* (circuit) in 4.4.4.2 in combination with a *PE conductor* in 4.4.4.3;
- automatic disconnection of supply in 4.4.4.4;
- supplementary *insulation* in 4.4.4.5;
- *basic protection* between circuits in 4.4.4.6; or
- *electrically protective screening* in 4.4.4.7.

Means used for *fault protection* shall be independent and additional to those for *basic protection*.

4.4.4.2 Protective equipotential bonding (circuit)

4.4.4.2.1 General

Protective equipotential bonding is a means for *fault protection* to enable protection against electric shock.

The *protective equipotential bonding* circuit consists of the interconnection of:

- *PE* terminal(s) of the *PECS* (see 4.4.4.3.2);
- the *PE conductors* (4.4.4.3) within and between the parts of the *PECS* including sliding contacts where they are part of the circuit; and
- the conductive structural parts and conductive *accessible parts* of the *PECS*.

Protective equipotential bonding shall be provided between conductive *accessible parts* of the *PECS* and the means of connection for the *PE conductor* in 4.4.4.3.2, to ensure automatic disconnection of the supply according to IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017, Clause 411 (see Annex Q), except where conductive *accessible parts* are protected by one of the means for *enhanced protection* in 4.4.5.4.

Protective equipotential bonding shall be suitably protected against mechanical damage, chemical or electrochemical degradation, electromagnetic and thermodynamic forces.

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

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.

Every connection (e.g. screwed, clamps) between *protective equipotential bonding* and other equipment shall provide durable electrical continuity and adequate mechanical strength and protection.

Screws for connecting *protective equipotential bonding* shall not serve any other purpose except when the manufacturer specifies this in the documentation.

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 (see Figure 4, key 8);
- through other conductive *accessible parts* or other metallic *components* which are not removed when the *PECS* is used as intended; or
- through metal *enclosures*, walls or frames.

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.

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, the metal sheathing of all connecting cables (for example cable armoring, lead sheath) shall be connected to the *protective equipotential bonding* circuit.

Where hazardous voltage on unused conductors is present due to capacitive or inductive coupling from adjacent conductors, the unused conductors 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.

For marking, see 6.3.9.3.