



BSI Standards Publication

Safety requirements for power electronic converter systems and equipment

Part 1: General

National foreword

This British Standard is the UK implementation of EN 62477-1:2012+A12:2021. It is derived from IEC 62477-1:2012, incorporating amendment 1:2016. It supersedes BS EN 62477-1:2012+A1:2017, which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to IEC text carry the number of the IEC amendment. For example, text altered by IEC amendment 1 is indicated by **A1** **A1**.

The UK participation in its preparation was entrusted to Technical Committee PEL/22, Power electronics.

A list of organizations represented on this committee can be obtained on request to its committee manager.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

This publication has been prepared under a mandate given to the European Standards Organizations by the European Commission and the European Free Trade Association and is intended to support essential requirements of the EU legislation detailed in the European foreword. Annex ZA/ZZ describes how the publication relates to the legislation.

For the Great Britain market (England, Scotland and Wales), if the UK Government has designated this publication for conformity with UKCA marking legislation and has not amended the essential requirements of that legislation, Annex ZA/ZZ and any references to EU law in the publication should be read in accordance with the designation as applying to UK legislation in the same way as to EU law. Further information on designated standards can be found at www.bsigroup.com/standardsandregulation.

For the Northern Ireland market, UK law will continue to implement relevant EU law subject to periodic confirmation. References to EU legislation are therefore still valid.

More information on legislation can be found at www.gov.uk.

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Published by BSI Standards Limited 2021

ISBN 978 0 539 16991 1

ICS 29.200

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 October 2012.

Amendments/corrigenda issued since publication

Date	Text affected
30 September 2014	Implementation of CENELEC amendment A11:2014: EN supersession information update

Date	Text affected
30 April 2017	Implementation of IEC amendment 1:2016 with CENELEC endorsement A1:2017
28 February 2021	Implementation of CENELEC amendment A12:2021: addition of Annex ZZ

**Safety requirements for power electronic converter systems
and equipment -
Part 1: General
(IEC 62477-1:2012)**

Exigences de sécurité applicables
aux systèmes et matériels électroniques
de conversion de puissance -
Partie 1: Généralités
(CEI 62477-1:2012)

Sicherheitsanforderungen an
Leistungshalbleiter-Umrichtersysteme
und -betriebsmittel -
Teil 1: Allgemeines
(IEC 62477-1:2012)

This European Standard was approved by CENELEC on 2012-08-28. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

European foreword

The text of document 22/200/FDIS, future edition 1 of IEC 62477-1, prepared by IEC/TC 22 "Power electronic systems and equipment" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62477-1:2012.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2013-05-28
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2015-08-28

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The text of the International Standard IEC 62477-1:2012 was approved by CENELEC as a European Standard without any modification.

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

IEC 60073:2002	NOTE	Harmonised as EN 60073:2002 (not modified).
IEC 60085	NOTE	Harmonised as EN 60085.
IEC 60216 Series	NOTE	Harmonised as EN 60216 Series (not modified).
IEC 60309-1	NOTE	Harmonised as EN 60309-1.
IEC 60664-5:2007	NOTE	Harmonised as EN 60664-5:2007 (not modified).
IEC 60695-11-5	NOTE	Harmonised as EN 60695-11-5.
IEC 60721 Series	NOTE	Harmonised as EN 60721 Series (not modified).
IEC 60947-7-1	NOTE	Harmonised as EN 60947-7-1.
IEC 60947-7-2	NOTE	Harmonised as EN 60947-7-2.
IEC 60950-1	NOTE	Harmonised as EN 60950-1.
IEC 61008 Series	NOTE	Harmonised as EN 61008 Series (partly modified).
IEC 61009 Series	NOTE	Harmonised as EN 61009 Series (partly modified).
IEC 61082-1	NOTE	Harmonised as EN 61082-1.
IEC 61140:2001	NOTE	Harmonised as EN 61140:2002 (not modified).
IEC 61508 Series	NOTE	Harmonised as EN 61508 Series (not modified).
IEC 61558-1	NOTE	Harmonised as EN 61558-1.
IEC 61558-2-16	NOTE	Harmonised as EN 61558-2-16.
IEC 61643-12	NOTE	Harmonised as CLC/TS 61643-12.
IEC 62079:2001	NOTE	Harmonised as EN 62079:2001 (not modified).
IEC 62423:2009	NOTE	Harmonised as EN 62423:2012 (modified).

Foreword to amendment A11

This document (EN 62477-1:2012/A11:2014) has been prepared by CLC/TC 22X "Power electronics".

The aim behind this Amendment is to link EN 62477-1:2012 to the Low Voltage Directive 2006/95/EC, further to a CLC/TC 22X request, approved by the Technical Board by the decision D146/C017.

In addition, a recent Technical Board decision (D147/C061), confirmed that EN 62477-1:2012 partially supersedes EN 50178:1997.

Add to the Foreword of EN 62477-1:2012:
"This document partially supersedes EN 50178:1997."

The following dates are fixed:

- latest date by which this document has (dop) 2015-07-18
to be implemented at national level by
publication of an identical national
standard or by endorsement
- latest date by which the national (dow) 2017-07-18
standards conflicting with this
document have to be withdrawn

This standard covers the Principle Elements of the Safety Objectives for Electrical Equipment Designed for Use within Certain Voltage Limits (LVD - 2006/95/EC).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Foreword to amendment A1

The text of document 22/270A/FDIS, future IEC 62477-1:2012/A1, prepared by IEC/TC 22 "Power electronic systems and equipment" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62477-1:2012/A1:2017.

The following dates are fixed:

- latest date by which the document has to be (dop) 2017-08-10
implemented at national level by
publication of an identical national
standard or by endorsement
- latest date by which the national (dow) 2020-02-10
standards conflicting with the
document have to be withdrawn

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The text of the International Standard IEC 62477-1:2012/A1:2016 was approved by CENELEC as a European Standard without any modification.

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

Addition:

IEC 60865 (series)	NOTE	Harmonized as EN 60865 (series).
IEC 60865-1	NOTE	Harmonized as EN 60865-1.
IEC 60909 (series)	NOTE	Harmonized as EN 60909 (series).
IEC 60909-0:2016	NOTE	Harmonized as EN 60909-0:2016.
IEC 60947-1:2007	NOTE	Harmonized as EN 60947-1:2007.
IEC 60947-6-1:2005	NOTE	Harmonized as EN 60947-6-1:2005.
IEC 60947-6-1:2005/AMD1:2013	NOTE	Harmonized as EN 60947-6-1:2005/A1:2014.
IEC 61439-1:2011	NOTE	Harmonized as EN 61439-1:2011.

Foreword to amendment A12

This document (EN 62477-1:2012/A12:2021) has been prepared by CLC/TC 22X "Power electronics".

The following dates are fixed:

- latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2021-08-05
- latest date by which the national standards conflicting with this document have to be withdrawn (dow) 2023-11-17

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This document has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For the relationship with EU Directive(s) see informative Annex ZZ, which is an integral part of this document.

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

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.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60050	Series	International Electrotechnical Vocabulary (IEV)	-	-
IEC 60060-1	2010	High-voltage test techniques - Part 1: General definitions and test requirements	EN 60060-1	2010
IEC 60068-2-2	-	Environmental testing - Part 2-2: Tests - Test B: Dry heat	EN 60068-2-2	-
IEC 60068-2-6	-	Environmental testing - Part 2-6: Tests - Test Fc: Vibration (sinusoidal)	EN 60068-2-6	-
IEC 60068-2-52	-	Environmental testing - Part 2-52: Tests - Test Kb: Salt mist, cyclic (sodium chloride solution)	EN 60068-2-52	-
IEC 60068-2-68	-	Environmental testing - Part 2: Tests - Test L: Dust and sand	EN 60068-2-68	-
IEC 60068-2-78	2001	Environmental testing - Part 2-78: Tests - Test Cab: Damp heat, steady state	EN 60068-2-78	2001
IEC 60112 + corr. June + corr. October	2003 2003 2003	Method for the determination of the proof and the comparative tracking indices of solid insulating materials	EN 60112	2003
IEC 60216-4-1	-	Electrical insulating materials - Thermal endurance properties - Part 4-1: Ageing ovens - Single-chamber ovens	EN 60216-4-1	-
IEC 60364-1	-	Low-voltage electrical installations - Part 1: Fundamental principles, assessment of general characteristics, definitions	HD 60364-1	-
IEC 60364-4-41 (mod)	2005	Low-voltage electrical installations - Part 4-41: Protection for safety - Protection against electric shock	HD 60364-4-41 + corr. July	2007 2007
IEC 60364-4-44 (mod)	2007	Low voltage electrical installations - Part 4-44: Protection for safety - Protection against voltage disturbances and electromagnetic disturbances	HD 60364-4-442	2012
IEC 60364-5-54	2011	Low-voltage electrical installations - Part 5-54: Selection and erection of electrical equipment - Earthing arrangements and protective conductors	HD 60364-5-54	2011

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60417-DB		Graphical symbols for use on 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)	EN 60529 + corr. May	1991 1993
IEC 60617-DB		Graphical symbols for diagrams	-	-
IEC 60664-1	2007	Insulation coordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests	EN 60664-1	2007
IEC 60664-3	2003	Insulation coordination for equipment within low-voltage systems - Part 3: Use of coating, potting or moulding for protection against pollution	EN 60664-3	2003
IEC 60664-4	2005	Insulation coordination for equipment within low-voltage systems - Part 4: Consideration of high-frequency voltage stress	EN 60664-4 + corr. October	2006 2006
IEC 60695-2-10	-	Fire hazard testing - Part 2-10: Glowing/hot-wire based test methods - Glow-wire apparatus and common test procedure	EN 60695-2-10	-
IEC 60695-2-11 + corr. January	2000 2001	Fire hazard testing - Part 2-11: Glowing/hot-wire based test methods - Glow-wire flammability test method for end-products	EN 60695-2-11	2001
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	EN 60695-2-13	-
IEC 60695-10-2	-	Fire hazard testing - Part 10-2: Abnormal heat - Ball pressure test	EN 60695-10-2	-
IEC 60695-11-10	-	Fire hazard testing - Part 11-10: Test flames - 50 W horizontal and vertical flame test methods	EN 60695-11-10	-
IEC 60695-11-20	-	Fire hazard testing - Part 11-20: Test flames - 500 W flame test methods	EN 60695-11-20	-
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	EN 60721-3-3	-
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	EN 60721-3-4	-

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60730-1	-	Automatic electrical controls for household and similar use - Part 1: General requirements	EN 60730-1	-
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 60990	1999	Methods of measurement of touch current and protective conductor current	EN 60990	1999
IEC 61032 + corr. January	1997 2003	Protection of persons and equipment by enclosures - Probes for verification	EN 61032	1998
IEC 61180-1	1992	High-voltage test techniques for low-voltage equipment - Part 1: Definitions, test and procedure requirements	EN 61180-1	1994
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 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	EN ISO 3746	-
ISO 3864-1	-	Graphical symbols - Safety colours and safety signs - Part 1: Design principles for safety signs in workplaces and public areas	-	-
ISO 7000	-	Graphical symbols for use on equipment - Index and synopsis	-	-
ISO 7010	-	Graphical symbols - Safety colours and safety signs - Registered safety signs	EN ISO 7010	-
ISO 9614-1	-	Acoustics - Determination of sound power levels of noise sources using sound intensity - Part 1: Measurement at discrete points	EN ISO 9614-1	-
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	-	-

Annex ZZ (informative)

Relationship between this European standard and the safety objectives of Directive 2014/35/EU [2014 OJ L96] aimed to be covered

This European standard has been prepared under a Commission's standardisation request relating to harmonised standards in the field of the Low Voltage Directive, M/511, to provide one voluntary means of conforming to safety objectives of Directive 2014/35/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits [2014 OJ L96].

Once this standard is cited in the Official Journal of the European Union under that Directive, compliance with the normative clauses of this standard given in Table ZZ.1 confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding safety objectives of that Directive, and associated EFTA regulations.

Table ZZ.1 – Correspondence between this European standard and Annex I of Directive 2014/35/EU [2014 OJ L96]

Safety objectives of Directive 2014/35/EU (Annex I)	Clause(s) / sub-clause(s) of this EN	Remarks / Notes
1. General:	Ref. of all Clauses from the CLC/TC 22X Committee standard, that are linked to the Safety Objectives	Remarks & Notes from CLC/TC 22X Secretariat
1 a) the essential characteristics, the recognition and observance of which will ensure that electrical equipment will be used safely and in applications for which it was made, shall be marked on the electrical equipment, or, if this is not possible, on an accompanying document	6	
1 b) the electrical equipment, together with its component parts, shall be made in such a way as to ensure that it can be safely and properly assembled and connected;	4.3, 4.8, 4.11 6.3, 6.4, 6.5	
1 c) the electrical equipment shall be so designed and manufactured as to ensure that protection against the hazards set out in points 2 and 3 is assured, providing that the equipment is used in applications for which it was made and is adequately maintained.	1, 2, 3 6.2, 6.4, 6.5	refer to 2a to 2d and 3a to 3c in this table

Safety objectives of Directive 2014/35/EU (Annex I)	Clause(s) / sub-clause(s) of this EN	Remarks / Notes
2. Protection against hazards arising from the electrical equipment		
2 a) persons and domestic animals are adequately protected against the danger of physical injury or other harm which might be caused by direct or indirect contact;	4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, 4.9. Annex A, Annex D, Annex F 5.1, 5.2.1, 5.2.2, 5.2.3, 5.2.4	
2 b) temperatures, arcs or radiation which would cause a danger, are not produced;	4.1, 4.2, 4.3, 4.5, 4.6, 4.9, 4.11, 4.12 5.1, 5.2.3.9, 5.2.4, 5.2.3.10, 5.2.5, 5.2.6	Hazards arising from electric, magnetic and electromagnetic fields, other ionizing and non-ionizing radiation are covered by separate standards.
2 c) persons, domestic animals and property are adequately protected against non-electrical dangers caused by the electrical equipment which are revealed by experience;	4.1, 4.2, 4.7, 4.12 5.1, 5.2.1, 5.2.2, 5.2.4	
2 d) the insulation is suitable for foreseeable conditions.	4.1, 4.2, 4.4.7, 4.6.4 5.1, 5.2.1, 5.2.3, 5.2.4, 5.2.5, 5.2.3.10	
3. Protection against hazards which may be caused by external influences on the electrical equipment		
3 a) meets the expected mechanical requirements in such a way that persons, domestic animals and property are not endangered;	4.1, 4.2, 4.7, 4.9, 4.12 5.1, 5.2.1, 5.2.2, 5.2.4, 5.2.6	
3 b) is resistant to non-mechanical influences in expected environmental conditions, in such a way that persons, domestic animals and property are not endangered;	4.1, 4.2, 4.9 5.1, 5.2.1, 5.2.6, 5.2.7	EMC is not covered
3 c) does not endanger persons, domestic animals and property in foreseeable conditions of overload.	4.1, 4.2, 4.3 5.1, 5.2.1, 5.2.4	

WARNING 1: Presumption of conformity stays valid only as long as a reference to this European standard is maintained in the list published in the Official Journal of the European Union. Users of this standard should consult frequently the latest list published in the Official Journal of the European Union.

WARNING 2: Other Union legislation may be applicable to the product(s) falling within the scope of this standard.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SAFETY REQUIREMENTS FOR POWER ELECTRONIC CONVERTER SYSTEMS AND EQUIPMENT –

Part 1: General

FOREWORD

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

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

- 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 publication using a colour printer.

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 62477-1:2012+A1:2016
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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

I_{cp}

r.m.s. 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 61439-1:2011, 3.8.7], modified – "ASSEMBLY" is replaced by "*PECS*".]

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.

3.66

conditional short-circuit current

I_{cc}

r.m.s. value of a *prospective short-circuit current* available from a supply source, declared by the PECS manufacturer under specified conditions, using a specific type of *short-circuit protective device* protecting the PECS

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

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

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

[SOURCE: IEC 61439-1: 2011. 3.8.10.4], modified – The definition is modified to fit to the use of PECS applications.]

3.67

current-limiting protective device

protective element that, during its operation and specified current range, limits the current to a substantially lower value than the peak value of the prospective current

Note 1 to entry: A current-limiting device is normally a current-limiting fuse or a current-limiting circuit breaker. See IEC 60050-441:1984, 441-18-10.

3.68

minimum required prospective short-circuit current

$I_{cp, mr}$

r.m.s. value of a minimum short-circuit current, which is needed to be available from a supply source in order to ensure safe interruption of the fault, and which is declared by the *PECS* manufacturer and tested under specified conditions, using a specific type of short-circuit protective device protecting the *PECS*.

3.69

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 – "conductor" deleted]

3.70

peak withstand current

I_{pk}

value of peak short-circuit current, declared by the *PECS* manufacturer, that can be carried without damage under specified conditions, defined in terms of current and time

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

Note 2 to entry: Time may be specified as the number of successive cycles at 50 Hz or 60 Hz.

[SOURCE: IEC 61439-1:2011, 3.8.10.2, modified – The definition is modified to fit to the use of *PECS* application.]

3.71

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 61439-1:2011, 3.1.11, modified – Note added]

3.72

short time withstand current

I_{cw}

r.m.s. value of short time current, declared by the *PECS* manufacturer, that can be withstood under specified conditions, defined in terms of current and time

[SOURCE: IEC 61439-1:2011, 3.8.10.3, modified – "rated" removed from the term and "ASSEMBLY" replaced by "PECS"] 

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.

A1 Components in 4.2 also include insulation systems, *ports*, etc. **A1**

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;

A1 • electromagnetic force and thermal hazard according to 4.3. **A1**

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).

A1 To ensure proper coordination with *short-circuit protective devices* and the available *prospective short-circuit current*, the *PECS* manufacturer shall specify and test for each *mains supply* input port of the *PECS*:

- *conditional short-circuit current* (I_{cc}) according to 4.3.2.2, or
- *rated short time withstand current* (I_{cw}) according to 4.3.5.

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 characteristic of *SCPD*, the I_{cw} in 4.3.5 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.

See Annex N for further information. **A1**

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*.

A1 4.3.2.2 Specification of the rated *conditional short-circuit current* (I_{cc}) on input *ports*

In case 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 and abnormal conditions, including insulation faults.

If it is shown by analysis that the result of one test is representative of the worst case, less severe combinations need not be tested. **A1**

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.

A1 4.3.5 Input ports short time withstand current, I_{cw}

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

- rated *short time withstand current* (I_{cw}),
- associated duration, and
- rated *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 5.2.4.10 in order to evaluate single fault and abnormal conditions, including insulation faults.

If it is shown by analysis that the result of one test is representative of the worst case, less severe combinations need not be tested. **A1**

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* A_x 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	Hand	Part of the body

cm ²	cm ²	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.

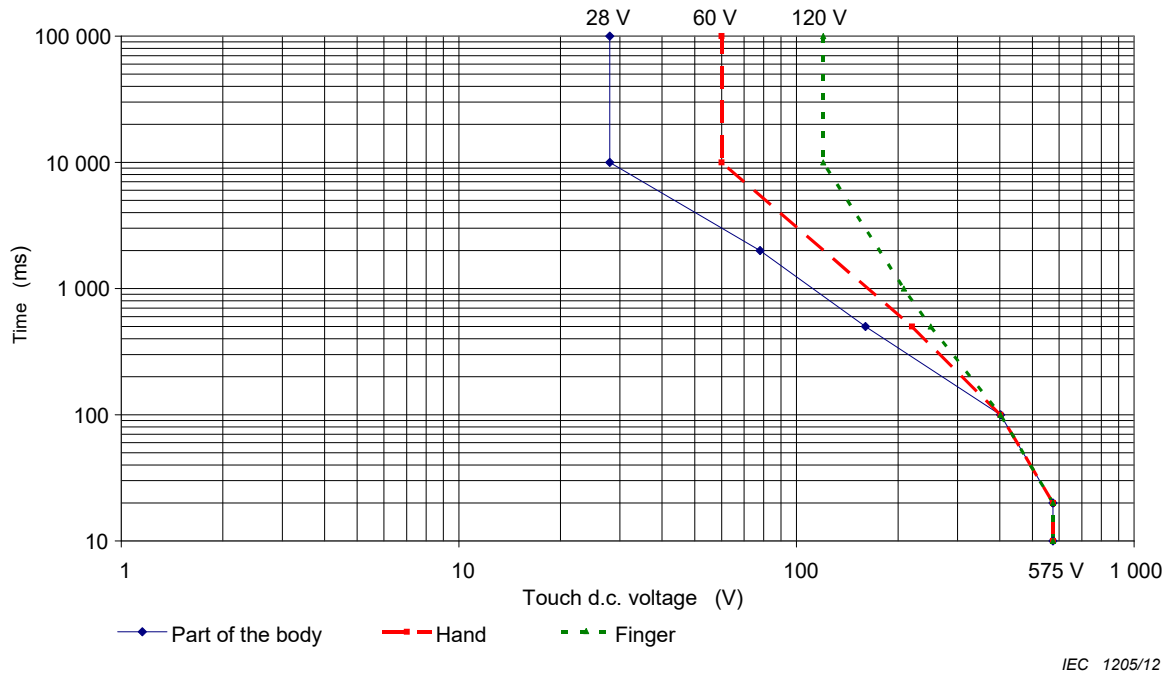


Figure 1 – Touch time - d.c. peak voltage zones of ventricular fibrillation in dry skin condition

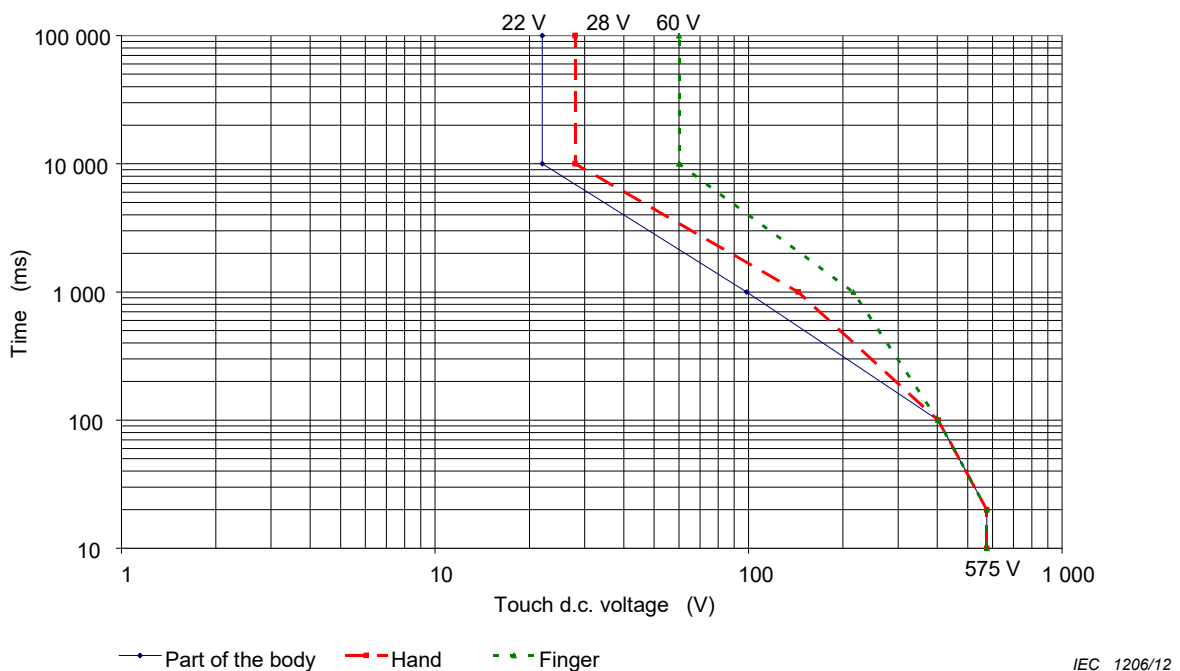
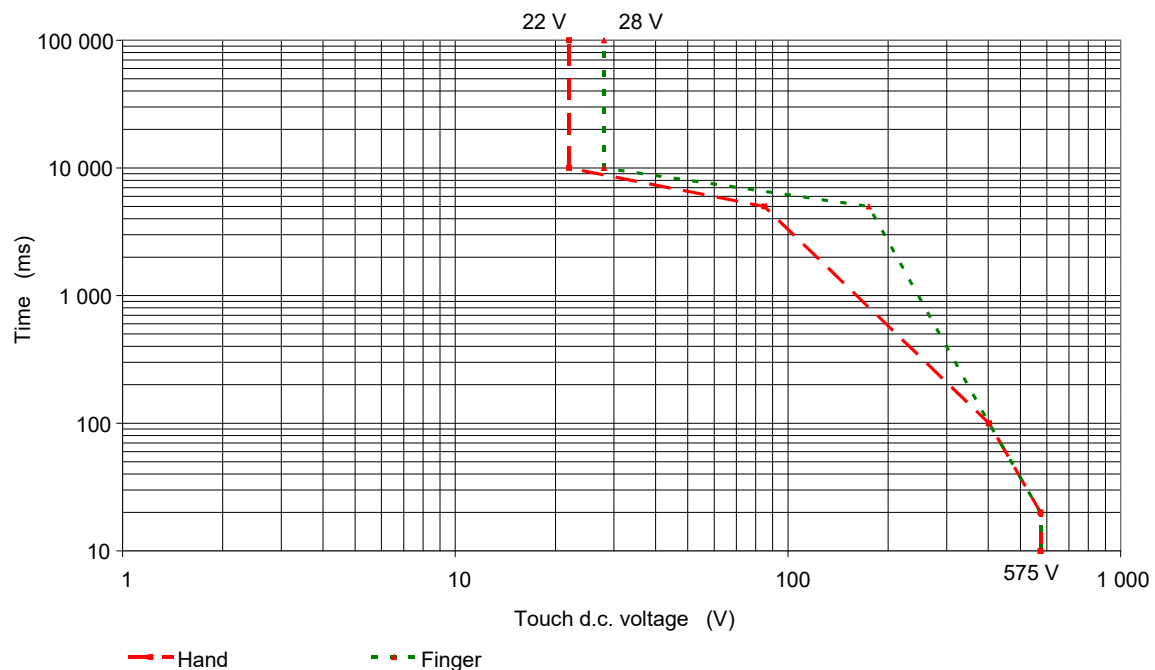


Figure 2 – Touch time - d.c. peak voltage zones of ventricular fibrillation in water-wet skin condition



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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 adjacent circuit 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
<p>NOTE 1</p> <p>1 Protection is not necessary for safety, but may be required for functional reasons according to 4.4.7.3.</p> <p>2 Basic protection for circuit of higher voltage.</p> <p>1 or 2 Depending on separation with other circuits.</p> <p>NOTE 2 Ax > As Voltage less than DVC B but higher than DVC As, that does not meet 4.4.2.2.</p> <p>^a A, A1, A2 or A3, which ever is appropriate according to 4.4.2.2.</p> <p>^b If the considered circuit is designated as a SELV circuit, basic protection is required from earth and from PELV circuits.</p> <p>^c Both circuits under consideration have the same DVC As level.</p> <p>^d Both circuits under consideration have different DVC As level.</p> <p>^e Except for Finger tip. See Table 2.</p> <p>^f Basic protection is required between galvanically isolated circuits (e.g. mains supply, UPS output, PV or generator output, auxiliaries).</p> <p>^g Also applies to conductive parts connected to functional earth.</p>						

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 μ C 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*.