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Responsible committee: GEL/82 Photovoltaic Energy Systems

Interested committees:

Title: BS EN IEC 62109-1 Safety of power converters for use in photovoltaic power systems

Part 1: General requirements

Please notify the secretary if you are aware of any keywords that might assist in classifying or identifying the standard or if the content of this standard

- i) has any issues related to 3rd party IPR, patent or copyright
- ii) affects other national standard(s)
- iii) requires additional national guidance or information

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Information on the co-operating organizations represented on the committees referenced above may be obtained from <http://standardsdevelopment.bsigroup.com>

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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

For national standards, comments will be reviewed by the relevant UK national committee and the resulting standards published as a British Standard.

UK Vote

Please indicate whether you consider the UK should submit a negative (with supporting technical reasons) or positive vote on this draft. Please indicate if you are aware of any reason why this draft standard should not be published as a British Standard.

Submission of Comments

- **Annotated drafts are not acceptable and will be rejected.**
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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

PROJECT NUMBER: IEC 62109-1 ED2	
DATE OF CIRCULATION: 2024-01-12	CLOSING DATE FOR COMMENTS: 2024-04-05
SUPERSEDES DOCUMENTS: 82/2160/RR	

IEC TC 82 : SOLAR PHOTOVOLTAIC ENERGY SYSTEMS	
SECRETARIAT: United States of America	SECRETARY: Mr George Kelly
OF INTEREST TO THE FOLLOWING COMMITTEES:	PROPOSED HORIZONTAL STANDARD: ☐ Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.
FUNCTIONS CONCERNED: ☐ EMC ☐ ENVIRONMENT ☐ QUALITY ASSURANCE ☒ SAFETY	

This document is still under study and subject to change. It should not be used for reference purposes.

Recipients of this document are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

Recipients of this document are invited to submit, with their comments, notification of any local regulations or technical reasons that may exist and should be considered should this proposal proceed, recognizing that failure to address such requirements could result in the need for new or existing "In Some Countries" clauses. (See [AC/22/2007](#) or [NEW GUIDANCE DOC](#)).

TITLE:

Safety of power converters for use in photovoltaic power systems – Part 1: General requirements

NOTE FROM TC/SC OFFICERS:

This project was discussed and supported by WG6 during their meeting in 2023-10.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**PHOTOVOLTAIC POWER SYSTEMS –
SAFETY – POWER CONVERSION EQUIPMENT –****Part 1: General requirements**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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IEC 62109-1 has been prepared by Working Group 6 of IEC technical committee 82: Solar photovoltaic energy systems. It is an International Standard.

This 2nd edition cancels and replaces the 1st edition published in 2010. This edition constitutes a technical revision.

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

Note to National Committees: This section will be completed for the CDV.

- a)
- b)

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

FDIS	Report on voting
82/XXX/FDIS	82/XXX/RVD

Full information on the voting for 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/publications.

A list of all parts of IEC 62109 series, under the general title *Photovoltaic power systems - Safety - Power conversion equipment*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under webstore.iec.ch in the data related to the specific publication. At this date, the document will be

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

1

INTRODUCTION

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This Part 1 of IEC 62109 specifies the safety requirements that are generally applicable to all equipment within its scope. For certain types of equipment, these requirements will be supplemented or modified by the special requirements of one or more subsequent Parts (for example IEC 62109-2, IEC 62109-3, etc.) of the IEC 62109 series which must be read in conjunction with these Part 1 requirements.

7

PHOTOVOLTAIC POWER SYSTEMS – SAFETY – POWER CONVERSION EQUIPMENT –

Part 1: General requirements

1 Scope

This Part 1 of the IEC 62109 series provides general requirements applicable to all types of power conversion equipment (PCE) for use in Photovoltaic (PV) systems where a uniform technical level with respect to safety is necessary. This standard defines the minimum requirements for the design and manufacture of PCE for protection against electric shock, energy, fire, mechanical and other hazards.

Equipment included in scope:

This document covers PCE with inputs and outputs not exceeding the low voltage limits of 1 500 V DC and 1 000 V AC, line to line and line to earth, including PV, battery, mains and non-mains AC systems, or other sources.

This standard may also be used for accessories for use with PV PCE, except where more appropriate standards exist.

PCE with multiple functions or modes shall be judged against all applicable requirements for each of those functions and modes.

Throughout this document, where terms such as “inverter” are used, the meaning is either a PCE that is an inverter or an inverter operating mode of a multi-mode PCE.

Aspects included in scope:

The purpose of the requirements of this Part 1 of IEC 62109 is to ensure that the design and methods of construction used in PV PCE provide adequate protection for the operator and the surrounding area against:

- a) electric shock and energy hazards;
- b) mechanical hazards;
- c) excessive temperature hazards;
- d) spread of fire from the equipment;
- e) chemical hazards;
- f) sonic pressure hazards;
- g) liberated fluids, gases and explosion hazards.

NOTE 1 Servicing personnel are expected to have the necessary knowledge and skill to use reasonable care in dealing with hazards associated with the operation, repair and maintenance of this equipment. Based upon this premise, this standard provides only limited requirements (for example markings or guarding) intended to protect service personnel from hazards that may not be apparent even to trained personnel.

Aspects not covered by this standard include, but are not limited to, the following:

- i) functional reliability, performance or other properties of the equipment not related to safety;
- ii) ability to withstand expected storage and transportation environments;
- iii) EMC requirements except where related to Functional Safety;

iv) installation requirements, which are covered by local and national installation codes.

NOTE 2 This standard does provide requirements intended to ensure that the PCE can be installed in a safe manner by skilled persons, including requirements for installation instructions provided with the product.

v) Transportable and handheld equipment

NOTE 3 The term transportable refers to equipment intended to be regularly moved between various operating sites. The term handheld refers to equipment intended to be held during operation. Neither of these conditions is typical for PV PCE.

vi) characteristics of power sources other than photovoltaic systems, such as wind turbines, fuel cells, rotating machine sources, etc.

vii) requirements for special installation environments such as explosive atmospheres (see IEC 60079), aircraft, marine installations, or electromedical applications (see IEC 60601)

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 60076 (all parts), *Power transformers*

IEC 60085, *Electrical insulation – Thermal evaluation and designation*

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

IEC 60216-5, *Electrical insulating materials – Thermal endurance properties – Part 5: Determination of relative thermal endurance index (RTE) of an insulating material*

IEC 60216-6, *Electrical insulating materials – Thermal endurance properties – Part 6: Determination of thermal endurance indices (TI and RTE) of an insulating material using the fixed time frame method*

IEC 60227 (all parts), *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V*

IEC 60228, *Conductors of insulated cables*

IEC 60245 (all parts), *Rubber insulated cables – Rated voltages up to and including 450/750 V*

IEC 60309 (all parts), *Plugs, socket-outlets and couplers for industrial purposes*

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

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

IEC 60364-5-54, *Electrical installations of buildings – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements, protective conductors and protective bonding conductors*

IEC 60384-14:2013, Amendment 1:2016, *Fixed capacitors for use in electronic equipment –*

- 87 *Part 14: Sectional specification – Fixed capacitors for electromagnetic interference*
88 *suppression and connection to the supply mains*
- 89 IEC 60417, *Graphical symbols for use on equipment*
- 90 IEC 60529, *Degrees of protection provided by enclosures (IP Code)*
- 91 IEC 60664-1:2020, *Insulation coordination for equipment within low-voltage systems – Part 1:*
92 *Principles, requirements and tests*
- 93 IEC 60664-3:2016, *Insulation coordination for equipment within low-voltage systems – Part 3:*
94 *Use of coating, potting or moulding for protection against pollution*
- 95 IEC 60664-4:2005, *Insulation coordination for equipment within low-voltage systems – Part 4:*
96 *Consideration of high-frequency voltage stress*
- 97 IEC 60695 (all parts), *Fire hazard testing*
- 98 IEC 60730-1:2022, *Automatic electrical controls for household and similar use – Part 1: General*
99 *requirements*
- 100 IEC 60755, *General requirements for residual current operated protective devices*
- 101 IEC 60947-6-1, *Low-voltage switchgear and controlgear - Part 6-1: Multiple function equipment*
102 *- Transfer switching equipment*
- 103 IEC 60898 (all parts), *Electrical accessories – Circuit-breakers for overcurrent protection for*
104 *household and similar installations*
- 105 IEC 60990:2016, *Methods of measurement of touch current and protective conductor current*
- 106 IEC 61032, *Protection of persons and equipment by enclosures – Probes for verification*
- 107 IEC 61180-1, *High-voltage test techniques for low voltage equipment – Part 1: Definitions, test*
108 *and procedure requirements*
- 109 IEC 61984, *Connectors - Safety requirements and tests*
- 110 IEC 62020, *Electrical accessories – Residual current monitors for household and similar uses*
111 *(RCMs)*
- 112 IEC 62310-1, *Static transfer systems (STS) - Part 1: General and safety requirements*
- 113 IEC 62368-1:2018, *Audio/video, information and communication technology equipment - Part 1:*
114 *Safety requirements*
- 115 IEC 62440, *Electric cables with a rated voltage not exceeding 450/750 V - Guide to use*
- 116 IEC 62477-1:2022 (2nd edition), *Safety requirements for power electronic converter systems and*
117 *equipment - Part 1: General*
- 118 IEC 62852, *Connectors for DC application in photovoltaic systems - Safety requirements and*
119 *tests*

- 120 IEC 62920:2017/Amd.1:2021 , *Photovoltaic power generating systems – EMC requirements and*
121 *test methods*
- 122 IEC 62930:2017, *Electric cables for photovoltaic systems with a voltage rating of 1,5 kV DC*
- 123 ISO 178, *Plastics – Determination of flexural properties*
- 124 ISO 179 (all parts), *Plastics – Determination of Charpy impact properties*
- 125 ISO 180, *Plastics – Determination of Izod impact strength*
- 126 ISO 261, *ISO general purpose metric screw threads – General plan*
- 127 ISO 262, *ISO general purpose metric screw threads – Selected sizes for screws, bolts and nuts*
- 128 ISO 527 (all parts), *Plastics – Determination of tensile properties*
- 129 ISO 3744, *Acoustics — Determination of sound power levels and sound energy levels of noise*
130 *sources using sound pressure — Engineering methods for an essentially free field over a*
131 *reflecting plane*
- 132 ISO 3746, *Acoustics – Determination of sound power levels of noise sources using sound*
133 *pressure – Survey method using an enveloping measurement surface over a reflecting plane*
- 134 ISO 4892-1, *Plastics – Methods of exposure to laboratory light sources – Part 1: General*
135 *guidance*
- 136 ISO 4892-2, *Plastics – Methods of exposure to laboratory light sources – Part 2: Xenon-arc*
137 *lamps*
- 138 ISO 4892-4, *Plastics – Methods of exposure to laboratory light sources – Part 4: Open-flame*
139 *carbon-arc lamps*
- 140 ISO 7000, *Graphical symbols for use on equipment – Index and synopsis*
- 141 ISO 8256, *Plastics – Determination of tensile-impact strength*
- 142 ANSI/ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building*
143 *Materials*
- 144 ANSI UL 50E, *Enclosures for Electrical Equipment, Environmental Considerations*
- 145 ANSI UL 746B, *Polymeric Materials – Long Term Property Evaluations*
- 146 ANSI UL 746C, *Polymeric Materials – Use in Electrical Equipment Evaluations*
- 147 ANSI UL 969, *Safety for Marking and Labeling Systems*
- 148 ASTM E162, *Standard Test Method for Surface Flammability of Materials Using a Radiant Heat*
149 *Energy Source*

3 Terms, definitions, symbols, and abbreviated terms

For the purposes of this document, the following terms, definitions, symbols, and abbreviated terms apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

Throughout this document, when a defined term is used in the text, it is formatted in *italics*.

Note to National Committees: This formatting will be done for the CDV.

162

Table 1 – Alphabetical Index of Terms

163 NOTE See also the terms specific to Functional Safety in B.2. Those terms are not included in this index.

164

accessible	3.1	adjacent circuit	3.2	backfeed	3.3
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165

166

3.1**accessible**

able to be touched with the standard access probes when used as specified in 7.3.4

3.2**adjacent circuit**

circuit next to the circuit under consideration, and separated from it by galvanic separation or by protective voltage limitation (per 7.3.5.4)

3.3**backfeed**

application of voltage or current from one energy source, onto a port provided for a different energy source, either intentionally or unintentionally

Note 1 to entry: An example of unintentional backfeed is current driven back through an inverter by energy from the grid, onto the PV input circuit under fault conditions. An example of intentional backfeed is application of a DC voltage onto the PV circuit at night, to reverse Potential Induced Degradation.

Note 2 to entry: In this document and in IEC 62548 Ed. 2, backfeed current is differentiated from PV reverse current. The PV reverse current and any potential backfeed current from an external battery onto the PV circuit are not included in the reported PCE backfeed current as the levels of those currents are dependent on site-specific design. Refer to 4.4.4.6.1 for requirements.

3.4**basic insulation****BI**

insulation which provides a single level of protection against electric shock under fault-free conditions

Note 1 to entry: Basic insulation may serve also for functional purposes.

3.5**battery type**

battery chemistry (e.g. lead-acid) and configuration (e.g. flooded, gel, flow etc.)

3.6**battery - sealed**

battery with no provision for the addition of water or electrolyte, and constructed so as to prevent the emission of liquid or gasses under normal operation

3.7**battery - non-sealed**

battery with removable caps or other provision for addition of water and/or electrolyte

3.8**battery - valve regulated**

sealed battery with provision for the release of excessive pressure under abnormal conditions

3.9**clearance**

shortest distance in air between two conductive parts

3.10**closed electrical operating area**

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

3.11**combustible material**

material that is capable of being ignited or burned

Note 1 to entry: All thermoplastic materials are considered capable of being ignited or burned regardless of the material flammability class.

Note 2 to entry: Examples of combustible materials include thermoplastic materials and those made of or surfaced with wood, compressed paper, plant fibers, or other materials that are capable of being ignited and burned.

[Source: IEC 62368-1, ed. 3.0 (2018-10) modified - Note 2 to entry is added]

3.12**comparative tracking index****CTI**

voltage, as determined under the conditions specified in IEC 60112, that causes a permanent electrically conductive carbon path with the application of 50 drops of electrolyte that is applied at the rate of one drop every 30 s to the specimen

3.13**creepage distance**

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

[IEV 151-03-37]

3.14**DC conditioning unit****DCU**

PCE converting DC input voltage and/or current to different DC output voltage and/or current levels. The DC input may be from one or more PV modules or strings, or another type of DC circuit

NOTE 1 to entry: DCU is a general term for PCE that convert DC to DC, for example optimizers, string-level DC-DC converters, etc. and may be for example a stand-alone device or a module-level converter.

NOTE 2 to entry: In this document, a DC to DC conversion stage integral to an inverter is not referred to as a DCU but as a DC-DC converter or DC-DC conversion stage or other similar wording. This distinction is relevant for certain requirements, for example due to a DCU having output field wiring, while a DC-DC converter is factory-assembled into the overall PCE (inverter).

3.15**decisive voltage classification****DVC**

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

Note 1 to entry: Classifications DVC A, B, and C are used. See decisive voltage class limits in 7.3.2

[Source: IEC 62477-1 Ed. 2 modified - Note 1 to entry has been added]

3.16**decorative part**

part of the equipment, outside the enclosure, which has no safety function

3.17**direct contact**

electric contact of persons or animals with live parts

Note 1 to entry: This term refers to the ability to touch live parts under normal conditions; see also “indirect contact”

[SOURCE IEC 195-06-03]

3.18**direct plug-in equipment**

equipment with a mains plug that is part of the equipment so that the equipment is supported by the mains receptacle

3.19**double insulation****DI**

insulation comprising both basic insulation and supplementary insulation

[IEV 195-06-08]

3.20**electrically instructed person****instructed person**

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 195-04-02]

3.21**electrically skilled person****skilled person**

person with relevant education and experience to enable him or her to perceive risks and to avoid hazards that electricity can create

[SOURCE: IEC 195-04-01]

3.22**enclosure**

part of the equipment which surrounds internal parts, intended to provide protection against external influences, against the spread of fire, or against access to hazards

3.23**environmental category**

set of ambient conditions to which the PCE is exposed in its installation, as defined in Clause 6

3.24**equipotential bonding**

provision of electric connections between conductive parts, intended to achieve equipotentiality

Note 1 to entry The effectiveness of the equipotential bonding may depend on the frequency of the current in the bonding.

[IEV 195-01-10]

3.25**equipotential bonding conductor**

conductor electrically connecting metal parts to provide equipotential bonding

3.26**EUT**

equipment under test

3.27**exposed-conductive-parts**

conductive part of equipment, which can be touched and which is not normally live, but which can become live when basic insulation fails

Note 1 to entry: A conductive part of electrical equipment which can only become live through contact with an exposed-conductive-part which has become live, is not considered to be an exposed-conductive-part itself. For example, consider a metal handle secured to the outside of a metal enclosure. If the enclosure (exposed-conductive-part) has a protective measure so that it cannot become live under single-fault conditions, then the handle is protected by that same protective measure, and does not need its own additional protective measure.

[IEV 195-06-10 modified: the example was added to Note 1]

3.28

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 AC RMS and 120 V DC

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

[IEV 826-12-30]

3.29

fire enclosure

a part of the equipment which surrounds internal parts, intended to minimize the spread of fire or flaming materials from within

3.30

fixed equipment

equipment fastened to a support, or otherwise secured in a specific location

[IEV 826-07-07]

3.31

flammability class

the recognition of the burning behaviour of materials and their ability to extinguish if ignited.

Note 1 to entry: Materials are classified when tested in accordance with IEC 60695-11-10, IEC 60695-11-20, ISO 9772 or ISO 9773

[IEV 903-05-01 modified Note 1 to entry: removed IEC 62368-1 specific details]

3.32

functional earth terminal

terminal by which electrical connection to earth is made from a conductor, part or circuit for any functional purpose other than safety

3.33

functionally earthed

functional earthing

intentionally connected to earth for any functional purpose other than safety

Note 1 to entry: Examples of functional array earthing include earthing one conductor through an impedance, relay, or overcurrent protective device, or systems in which the array is not permanently earthed (opening the earth connection periodically or under fault conditions).

Note 2 to entry: Connection to earth through a very high impedance does not create a functionally earthed system. For example, the high impedance resistive network to earth in an insulation monitor does not create a functionally-earthed array, as the impedance of such measurement networks is normally very high. This standard does not set a limit for the threshold below which the resistance creates a functionally earthed system, but such a limit may be given in installation codes or other standards.

Note 3 to entry: In Ed. 1 of IEC 62109-2, the term "functionally earthed" was used for arrays that connected to earth through an intentional impedance. The term "grounded" was used for arrays that connected to earth through negligible impedance but had a fuse, relay, etc. in the path. The above revised definition in this Ed. 2 of Part 1 includes both of those situations, and therefore is a significant terminology change between the 1st and 2nd editions of the IEC 62109 standards. This change is aligned with the approaches in IEC 62548, IEC 63112 (which includes informative illustrations of system types), and IEC 60364-7-712.

3.34
functional insulation
FI

insulation between conductive parts which is necessary only for the proper functioning of the equipment

Note 1 to entry: Functional insulation by definition does not protect against electric shock. It may, however, reduce the likelihood of ignition and fire.

[IEV 195-02-41 modified: Note 1 has been added]

3.35
functional safety
FS

correct operation of the declared safety function(s), failure or malfunction of which can cause a hazard

Note 1 to entry: The hazard could result from a loss of protective function leading to a risk of explosion, excessive temperature, electric shock, fire and/or personal injury, etc.

[IEC 60730-1, ed 6.0 (2022-09) modified: changed “safety related output function(s)” to “safety function(s)” and deleted “(output function)” from the Note]

3.36
gasket

material introduced between mating surfaces of an enclosure which in compression forms a joint

[IEC 60670-1, ed. 2.0 (2015-03)]

3.37
grid-interactive

intended to export power to the grid (AC mains)

NOTE Also commonly referred to as “grid-connected”, “grid-tied”, “utility-interactive”. Power exported may or may not be in excess of the local load

3.38
hazard

potential source of harm from any of the mechanisms covered by this standard, such as risk of electric shock, risk of fire, etc.

[IEV 903-01-02 modified by adding “from any of...risk of fire, etc.”]

3.39
hazardous energy level

available energy level of 240 VA or more having a duration of 60 s or more, or a stored energy level of 20 J or more (for example, from one or more capacitors), at a potential of 2 V or more (see 7.4.1)

3.40
hazardous live

circuit or live part that does not comply with the shock hazard limits in 7.3 or energy hazard limits in 7.4 and is therefore capable of rendering an electric shock or burn.

3.41**hermetically sealed enclosure**

enclosure which is so constructed that the external atmosphere cannot gain access to the interior, and in which any seal is made by fusion, for example, brazing, welding or the fusion of glass to metal

[IEV 426-09-11, modified; the word “device” is replaced with “enclosure”]

3.42**homogeneous field**

<distribution of an electric field> electric field which has an essentially constant voltage gradient between electrodes (i.e. a uniform field)

3.43**Indirect contact**

Electric contact of persons or livestock with exposed-conductive-parts which have become live under fault conditions

NOTE 1 to entry: Protection against indirect contact is equivalent to “fault protection” in IEC 61140 and IEC 62477-1

NOTE 2 to entry: This term refers to parts which are not normally live, but have become live due to an accidental insulation failure or some other fault.

[IEV 195-06-04]

3.44**indoor, unconditioned**

equipment environmental classification in which the PCE is fully covered by a building or enclosure to protect it from direct rain, sun, wind-blown dust, fungus, and radiation to the cold night sky, etc., but the building or enclosure is not conditioned in terms of temperature, humidity or air filtration, and the equipment may experience condensation

3.45**indoor, conditioned**

equipment environmental classification in which the PCE is fully covered by a building or enclosure to fully protect it from rain, sun, wind-blown dust, fungus, and radiation to the cold night sky, etc., and the building or enclosure is generally conditioned in terms of temperature, humidity and air filtration. Condensation is not expected

3.46**inhomogeneous field**

<distribution of an electric field> electric field not having an essentially constant voltage gradient between electrodes (i.e. a non-uniform field)

3.47**inverter**

Power Conversion Equipment (PCE) that converts direct current to alternating current

Note 1 to entry: Such equipment may also be bi-directional and rectify AC to DC in other operating modes.

3.48**limited power source**

source complying with the requirements in 9.2 of this standard

3.49**liquid-immersed type transformer**

transformer in which the magnetic circuit and windings are immersed in liquid

[IEC 60076-1]

3.50**live part**

conductor or conductive part intended to carry current or be energized in normal use, including earthed or functionally earthed conductors, but not including protective earthing (PE, PEN, PEM, or PEL) conductors

Note 1 to entry: Examples of live parts include energized parts and conductors, functionally earthed PV conductors, and an AC neutral conductor,

Note 2 to entry: PE, PEN, PEM, and PEL are described in IEC 60364-1

3.51**low voltage**

a set of voltage levels used for the distribution of electricity and whose upper limit of the line-to-line or line-to-neutral voltage is 1 000 V AC or 1 500 V DC

3.52**mains**

low-voltage AC electricity distribution system to which the PCE is designed to be connected

3.53**mains circuit**

circuit which is intended to be conductively connected to the mains

3.54**maximum limited current rating - bus** **$I_{BUS\ MAX}$**

Maximum limited current rating under normal conditions specified for the output of a group of PCE in accordance with 4.9

3.55**maximum limited current rating - PCE** **$I_{PCE\ OUT\ MAX}$**

Maximum limited current rating under normal conditions specified for the output of a PCE in accordance with 4.9

Note 1 to entry: In IEC 62548 Ed. 2 (in preparation) the term $I_{DCU\ max}$ is used and is specific to the output of a DCU

3.56**maximum overcurrent protection rating - DCU** **$I_{DCU\ max}$**

DCU maximum overcurrent protection rating on the DCU output

Note 1 to entry: This may be given as a fuse rating.

[Source: IEC 62548 Ed. 2 (in preparation) - modified: "DCU string output" is changed to "DCU output"]

3.57**neutral**

current-carrying conductor, terminal, or circuit point which is intentionally bonded to earth

Note 1 to entry: The terms earthed neutral and grounded conductor are also in common use. In this standard, the term neutral refers to an earthed conductor in any power circuit (mains, PV, battery, etc.) not just the AC mains. For PV circuits see also the term "functionally earthed".

3.58**normal condition**

condition in which all means for protection against hazards are intact and the PCE is installed and operated in accordance with its ratings and installation instructions

3.59**normal use**

operation, including stand-by, according to the instructions for use or for the obvious intended purpose

Note 1 to entry: In most cases, normal use also implies normal condition, because the instructions for use will warn against using the equipment when it is not in normal condition.

3.60**operator**

person who is neither a skilled person nor an instructed person (i.e. an ordinary person), commanding and monitoring, but not changing, the equipment for its intended purpose

3.61**operator access area**

part of the PCE to which, under normal operating conditions, one of the following applies:

- access can be gained without the use of a tool,
 - the means of access is deliberately provided to the operator, or
 - the operator is instructed to enter regardless of whether a tool is needed to gain access,
- and which is free from hazards.

3.62**outdoor**

equipment environmental classification in which the PCE is fully or partly exposed to direct rain, sun, wind, dust, fungus, ice, condensation, radiation to the cold night sky, etc., and to the full range of outdoor temperature and humidity; wet location requirements apply

3.63**overvoltage category****OVC**

numeral designation defining a classification of transient overvoltage conditions

Note 1 to entry: See 7.3.7.1.3 for a description of the four overvoltage categories.

Note 2 to entry: A transient overvoltage is defined as a 'short duration overvoltage of a few milliseconds or less, oscillatory or non-oscillatory, usually highly damped' [IEV 604-03-13]. It should not be confused with a temporary overvoltage (swell), which is defined as a 'power frequency overvoltage of relatively long duration' [IEV 616-01-16].

[SOURCE: IEC 581-21-02, modified – Notes 1 and 2 to entry have been added.]

3.64**partial discharge extinction voltage** **U_e**

lowest peak value of the test voltage at which the apparent charge becomes less than the specified discharge magnitude when the test voltage is reduced below a high level where such discharges have occurred

Note 1 to entry: For AC tests the RMS value may be used.

[SOURCE: IEC 60664-1:2020, cl. 3.1.39]

3.65**permanently connected**

electrically connected by means which can be detached only by the use of a tool

3.66**protective extra low voltage system****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

[IEV 295-06-29, modified: Note 1 to entry is removed, and the full term is added above the acronym]

3.67**photovoltaic****PV**

relating to the conversion of light directly into electrical energy

3.68**photovoltaic array**

assembly of components such as photovoltaic panels, cables, connectors, combiners, etc., that produces and supplies DC electricity by the conversion of solar energy

3.69**photovoltaic circuit**

electrical circuit including PV modules, strings, subarrays, or the entire array, including any DCU's located in the strings or at the modules

3.70**pluggable equipment type A**

equipment which is intended for connection to the AC system via a non-industrial plug and socket-outlet or a non-industrial appliance coupler, or both

3.71**pluggable equipment type B**

equipment that is intended for connection to the mains via a locking industrial plug and socket-outlet or via an industrial appliance coupler, or both.

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

[Source IEC 904-04-09 modified - the word "locking" has been added]

3.72**pollution**

addition of foreign matter, solid, liquid or gaseous (ionized gases), that may produce a reduction of dielectric strength or surface resistivity

3.73**pollution degree**

numeral characterizing the expected pollution of the micro-environment

Note 1 to entry: Pollution degrees 1, 2, 3 and 4 are used, see 6.2 and terms 3.74 - 3.77

[SOURCE: IEC 60664-1:2020 modified: Note 1 to entry has been added]

3.74**pollution degree 1****PD1**

Environment in which no pollution or only dry, non-conductive pollution occurs; the pollution has no influence

[SOURCE: IEC 60664-1:2020 modified: “environment in which” has been added]

3.75**pollution degree 2****PD2**

environment in which only non-conductive pollution occurs except that occasionally, a temporary conductivity caused by condensation is to be expected. This condensation may occur during periods of on-off load cycles of the equipment.

[SOURCE: IEC 60664-1:2020 modified: “environment in which” has been added]

3.76**pollution degree 3****PD3**

environment in which conductive pollution occurs, or dry, non-conductive pollution occurs which becomes conductive due to condensation which is expected

[SOURCE: IEC 60664-1:2020 modified: “environment in which” has been added]

3.77**pollution degree 4****PD4**

environment in which continuous conductivity occurs due to conductive dust, rain, or other wet conditions.

[SOURCE: IEC 60664-1:2020 modified: “environment in which” has been added]

3.78**port**

terminal or set of terminals where the PCE connects to conductors of an external power, control, or communications system

3.79**portable equipment**

pluggable equipment intended to be moved from place to place

3.80**power conversion equipment****PCE**

electrical device converting one kind of electrical power from a voltage or current source into another kind of electrical power with respect to voltage, current or frequency

Note 1 to entry: Examples include AC-DC converters, DC-AC inverters, DC-DC converters, charge controllers, frequency converters, etc.

3.81**prospective short circuit current** **I_{CP}**

RMS value of the available current which would flow from a source connected to a port of the PCE, if the supply conductors from the source were short-circuited by a conductor of negligible impedance located as near as practicable to the supply terminals of the PCE

[SOURCE: IEC 62477-1, modified]

3.82

prospective short circuit current rating (of a port)

value of prospective short circuit current that a power port of the PCE is rated to have connected to it

NOTE 1 to entry: The prospective short circuit rating of a port is intended to convey to the installer the maximum fault current considered in evaluating and testing the PCE to the requirements in this document relating to safety under fault conditions. The rating may be accompanied by a specification for the duration of the fault current or for required overcurrent protective device characteristics to limit the magnitude and/or duration of the fault current.

NOTE 2 to entry: In general, the prospective short circuit current is represented by the symbol I_{cp} . In the case of a particular port of the PCE (e.g. the PV input), the symbol may have the port type added to it (e.g. $I_{cp\ PV}$ as in 3.83).

3.83

prospective short circuit current rating - PV port

$I_{cp\ PV}$

PCE maximum rated prospective short circuit current (see 3.81) at the PV input terminals; i.e. the absolute maximum current the PV input to the PCE is designed to withstand or carry under normal and fault conditions.

Note 1 to entry: At the system design level, this rating would typically be coordinated with the total short circuit current (I_{sc}) of the connected PV strings, adjusted for temperature, excess irradiance, etc. as required by installation standards (i.e. not simply the sum of the marked I_{sc} ratings of the connected PV modules, since those markings are based on short-circuit conditions under standard test conditions (STC), and may be exceeded in actual use).

Note 2 to entry: For a PCE with more than 1 PV input, an ICP PV rating is assigned to each input; the PCE may also have an overall total ICP PV in some cases.

3.84

protective bonding

electrical connection of accessible conductive parts or of protective screening to provide electrical continuity to the protective conductor terminal

3.85

protective bonding conductor

a conductor used to interconnect accessible conductive parts or protective screening for the purpose of protective bonding

3.86

protective class I

protection against electric shock by means of basic insulation and protective earthing of accessible conductive parts, so that accessible conductive parts cannot become live in the event of a failure of the basic insulation

3.87

protective class II

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

3.88

protective class III

protection against electric shock relying upon supply from DVC A circuits and in which voltages higher than DVC A are not generated

Note 1 to entry: For class III equipment, although there is no requirement for protection against electric shock, all other requirements of the standard apply.

3.89**protective earthing**

connection of a point in the equipment, system, or installation to earth, for protection against electric shock in case of a fault

3.90**protective earthing conductor**

conductor used to connect an equipment, system, or installation to earth, for protection against electric shock in case of a fault

3.91**protective conductor terminal**

terminal which is bonded to conductive parts of an equipment for safety purposes and is provided for the connection of a protective earthing conductor

3.92**protective impedance**

component or assembly of components whose impedance and construction limit steady-state touch current and electric charge to non-hazardous levels under normal and single fault conditions

Note 1 to entry: This protection measure creates a touch-safe DVC B or C circuit from a hazardous DVC B or C circuit; refer to requirements in 7.3.5.3. As the voltage is not necessarily reduced, it does not create a DVC A circuit.

[SOURCE: IEC 60050-826:2004, 826-12-35, modified – deleted “device”, and changed “are intended to limit” to “limit” and added “under normal and single fault conditions”]

3.93**protective separation**

separation between circuits or between conductive parts and circuits, by means of:

- double insulation,
- basic insulation and electrically protective screening (shielding), or
- reinforced insulation,

Note 1 to entry: This definition differs from that used (e.g.) in IEC 61140, in that in this standard protective separation includes separation from conductive parts to circuits, not only between circuits.

[SOURCE: IEC 60050-195: 1998/AMD1:2001, 195-06-19, modified - added “or between conductive parts and circuits”, and NOTE 1 to entry]

3.94**protective voltage limitation**

component or assembly of components that reduce the voltage of a source to a non-hazardous level under normal and single fault conditions

Note 1 to entry: This protection measure creates a DVC A circuit from a non-DVC A circuit; refer to requirements in 7.3.5.4

3.95**PV reverse current**

current supplied by parallel PV strings or sub-arrays into a fault on a string or sub-array and which does not include backfeed current.

Note 1 to entry: See 4.4.4.6.1 for requirements.

[IEC 62548 Ed. 2, modified - added “which” and Note 1 to entry]

706
707

708 **3.96**
709 **rated**

710 value assigned, generally by a manufacturer, to a specified operating condition of a component,
711 device or equipment

712 [IEV 151-04-03]

713 **3.97**
714 **rating**

715 set of rated values and operating conditions

716 [IEV 151-04-04]

717 **3.98**
718 **reference test conditions**

719 electrical, operating, and environmental conditions under which testing is to be performed, as
720 specified in 4.2.2

721 **3.99**
722 **reinforced insulation**
723 **RI**

724 single insulation system applied to live parts, which provides a degree of protection against
725 electric shock equivalent to double insulation under the conditions specified

726 Note 1 to entry: A single insulation system does not imply that the insulation must be one homogeneous piece. It
727 may comprise several layers which cannot be tested singly as basic or supplementary insulation.

728 **3.100**
729 **residual-current**

730 vector sum of the currents flowing in the normally current carrying conductors of a mains circuit,
731 expressed as an RMS value

732 **3.101**
733 **risk**

734 combination of the probability of the occurrence of harm and the severity of that harm

735 **3.102**
736 **routine test**

737 test to which each individual device (equipment) is subjected during or after manufacture to
738 ascertain whether it conforms to certain criteria

739 [IEV 151-04-16, modified]

740 **3.103**
741 **safety function**

742 function or system of the *PCE* which provides *functional safety*

743 **3.104**
744 **safety interlock**

745 means either of preventing access to a hazardous area until the hazard is removed, or of
746 automatically removing the hazardous condition when access is gained

747 **3.105**
748 **sample test**

749 test performed on less than 100% of production of a product, part, or material, where the number
750 of samples is determined according to a sampling plan

751 Note 1 to entry: Sample plans are often determined according to standards, such as ISO 2859-1 and MIL 105E

752 **3.106**

753 **secondary circuit**

754 circuit which has no direct connection to a mains circuit and derives its power from a
755 transformer, converter or equivalent separation device, or from a battery or other power source
756 not connected to the mains (e.g. the PV circuit in isolated PCE)

757 **3.107**

758 **safety extra low voltage system**

759 **SELV system**

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

761 – under normal conditions and

762 – under single fault conditions, including earth faults in other electric circuits

763 [IEV 195-06-28, modified: Note 1 to entry is removed, and the full term is added above the
764 acronym]

765 **3.108**

766 **separation**

767 prevention of electrical conduction between circuits or between conductive parts and circuits

768 Note 1 to entry: Examples of separation are isolating transformers (which use electromagnetic induction) or opto-
769 couplers (which use light to couple signals), which provide galvanic isolation between circuits, or insulation between
770 a live part and a conductive part.

771 Note 2 to entry: Separation does not imply a level of safety - it can be functional insulation or a higher degree such
772 as simple separation, double or reinforced insulation, or protective separation.

773 Note 3 to entry: This definition differs from that used (e.g.) in IEC 61140: in this standard separation includes
774 separation from conductive parts to circuits, not only between circuits.

775 **3.109**

776 **service personnel**

777 electrically skilled or electrically instructed person with training or instruction regarding PV PCE
778 servicing procedures

779 **3.110**

780 **simple separation**

781 separation between electric circuits or between an electric circuit and conductive parts or local
782 earth by means of basic insulation

783 [IEV 826-12-28 modified (added “conductive parts or”)]

784 **3.111**

785 **single fault condition**

786 condition in which there is a fault of a single protection or of a single component or a device

787 Note 1 to entry: If a single fault condition results in one or more other fault conditions, all are considered as one
788 single fault condition.

789 Note 2 to entry: “Single protection” means, for example, basic insulation or simple separation, and excludes measures
790 such as reinforced insulation or protective impedance since those cannot be defeated by a single fault.

791 [SOURCE IEC 903-01-15 modified: “(but not a reinforced protection)” is removed and Note 2 is
792 added]

3.112**supplementary insulation****SI**

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

3.113**terminal**

conductive part of a device, electric circuit or electric network, provided for connecting that device, electric circuit or electric network to one or more external conductors

Note 1 to entry: Terminals can contain one or several contacts and the term as used generally in this document therefore includes sockets, connectors, etc.

[IEV 151-12-12, modified - the original Note regarding other meanings is deleted and replaced with the above Note 1 to entry]

3.114**tool**

a screwdriver, coin, key, or any other object that is used to operate a screw, latch, or similar fastening means

3.115**touch safe DVC B or C circuit**

DVC B or C circuit whose touch current and energy are limited by protective impedance from a connected DVC B or C circuit, and that has protective separation from hazardous live parts of any circuit including the connected circuit.

3.116**type test**

conformity test made on one or more items representative of the production

[IEV 151-16-16]

3.117**maximum limited voltage rating - bus** **$U_{\text{BUS MAX}}$**

Maximum limited voltage rating under normal conditions specified for the output of a group of PCE in accordance with 4.9

3.118**maximum limited voltage rating - PCE** **$U_{\text{PCE OUT MAX}}$**

Maximum limited voltage rating under normal conditions specified for the output of a PCE in accordance with 4.9

Note 1 to entry: In IEC 62548 Ed. 2 (in preparation) the term $U_{\text{DCU MAX}}$ is used and is specific to the output of a DCU

3.119**maximum rated DC input voltage****separation $U_{\text{DC MAX}}$**

maximum rated DC input voltage a DC port of the PCE is designed to withstand (e.g. PV array maximum open-circuit voltage under worst-case conditions of ambient temperature, irradiance, etc.).

Note 1 to entry: This term generalizes the former $V_{\text{MAX PV}}$ to be applicable to any DC port including the PV port, a battery port, etc. In IEC 62894 and EN50524 the term used is $V_{\text{dc MAX}}$ and is specific to the PV input port. In IEC 62548 Ed. 2 the PV array maximum open circuit voltage is given the symbol $U_{\text{OC MAX}}$ which is intended to be coordinated with (i.e. to not exceed) the $U_{\text{DC MAX}}$ rating for the PCE PV input port.

3.120**wet location**

location where water or another conductive liquid may be present and is likely to cause reduced human body impedance due to wetting of the contact between the human body and the equipment, or wetting of the contact between the human body and the environment

3.121**working voltage**

voltage which occurs by design in a circuit or across insulation, under worst-case normal operating conditions. See 7.3.2.6

Acronyms:

The following list includes acronyms used in this document that are not already explained in the list of Terms above.

Note to National Committees: This list will be completed between CD and CDV, or if there is little or no need, the list will be eliminated.

– IWVR - Impulse Withstand Voltage Rating (see 7.3.7)

–

4 General requirements and testing**4.1 General**

This clause of this standard provides:

- requirements that are general in nature and are not related to one particular type of hazard (for example PV earth fault protection which relates to both fire and shock hazards)
- general conditions and requirements under which testing shall be carried out;
- some of the actual tests required to be performed, where those tests are general in nature and are not specifically related to one particular type of hazard (for example thermal tests).

Other tests and requirements that are specific to a particular type of hazard are located in the appropriate clause elsewhere in this standard.

Tests on subassemblies of the equipment meeting the requirements of the relevant reference standards specified in this standard, and used in accordance with them and in conditions not more severe than those applied during testing to determine compliance with the reference standards, need not be repeated during type tests of the whole equipment unless otherwise specified.

To ensure that equipment will not become hazardous in expected humidity conditions, as specified in Table 5, the EUT is to be subjected to humidity preconditioning according to 4.5 before certain tests, where specified elsewhere in this standard.

Where a measured value is close to a compliance limit, analysis of the measurement uncertainty shall be done to determine compliance.

Unless otherwise specified, values of "voltage" and "current" are the RMS values of an alternating, direct or composite voltage or current.

Compliance with the requirements of this standard is checked by carrying out all applicable tests in this standard, except that a test may be omitted if examination of the equipment demonstrates conclusively that the equipment would pass the test.

Tests are carried out under reference test conditions (see 4.2.2), and tests under both normal and single fault conditions are specified.

4.2 General conditions for testing

4.2.1 Sequence of tests

The sequence of tests is optional unless otherwise specified in this standard. The EUT shall be carefully inspected for damage creating a possible hazard in the meaning of this standard, after each test. The same sample need not be used for all tests unless otherwise specified in this standard.

4.2.2 Reference test conditions

4.2.2.1 Environmental conditions

Unless otherwise specified in this standard, for example with regard to environmental category as defined in 6.1, the following ambient environmental conditions shall exist in the test location:

- a) temperature of 15 °C to 40 °C;
- b) a relative humidity of not more than 75 % and not less than 5 %;
- c) an air pressure of 75 kPa to 106 kPa;
- d) no frost, dew, percolating water, rain, solar radiation, etc.

4.2.2.2 State of equipment

The product being subjected to type tests shall be physically and electrically representative of the future production products such that the evaluations per this standard adequately represent future production units.

Unless otherwise specified, each test shall be carried out on the equipment assembled for normal use and under the least favourable combination of the conditions given in 4.2.2.1 to 4.2.2.9, taking into account the PCE manufacturer's ratings, installation and operation instructions. If it is impractical to carry out particular tests on a complete EUT, tests on subassemblies are allowed, provided it is verified that the assembled equipment will meet the requirements of this standard.

4.2.2.3 Position of equipment

The equipment shall be installed in accordance with the manufacturer's instructions, in the configuration that results in the worst-case test conditions. Consideration shall be given to effects of ventilation, building into a wall, recess, cabinet, etc., installation in close proximity to structures, other equipment, etc.

4.2.2.4 Accessories

Accessories and operator-interchangeable parts available from, or recommended by, the manufacturer for use with the EUT shall be either connected or not connected, whichever is least favourable.

4.2.2.5 Covers and removable parts

Covers or parts, which can be removed without using a tool, shall be removed or not removed, whichever is least favourable.

4.2.2.6 External sources of supply

NOTE In this section, the terms “sources of supply” and “supply” refer to an external circuit having available power or energy, regardless of the direction of current, power, or energy flow during PCE operation, which can vary depending on operating mode(s), fault conditions, etc. For example for a grid-interactive inverter the AC mains is normally a load, but it is energized itself regardless of the PCE, and is a source of supply in this context.

4.2.2.6.1 General

During testing, the EUT input and output ports shall be connected to external AC or DC sources of supply as required for operation and in accordance with the manufacturer's instructions.

Tests for which the outcome will not be significantly affected by the supply conditions, may be carried out at any supply conditions within the manufacturer's ratings.

For tests for which the outcome may be significantly affected by supply conditions, the test shall be performed at the worst-case supply condition or conditions, taking into consideration multiple rated conditions and tolerances on rated conditions, as specified below

- a) Voltage: Tolerance shall be taken as 90 % to 110 % of the rated voltage(s), unless a wider range is given in the manufacturer's specifications for the EUT in which case the wider range is used. For circuits other than AC mains, if the EUT will not operate across the full 90 % to 110 % range, the tolerance is taken as the specified operating range. Testing at nominal supply voltage is acceptable except where specified elsewhere in this document, or if testing at the ends of the ranges is worst-case.
- b) Frequency: Tests may be performed at the rated nominal frequency or for equipment rated for both 50Hz and 60Hz, at either nominal frequency, except where frequency may affect the outcome of a test:
 - testing shall be performed at the worst case nominal frequency, or if that cannot be determined by analysis, at both nominal frequencies, and
 - where the EUT is rated for an operating range around either nominal frequency exceeding +/- 2Hz, testing shall be performed at the worst case end or ends of the range
- c) Polarity: For single-phase pluggable equipment type A, consideration is to be given to connection in both normal and reverse polarity conditions, if the outcome of a particular test could be affected.
- d) Earthing: The test supply shall be earthed or not according to the intended supply configuration for the equipment under test. For equipment that may be supplied from either an earthed or un-earthed supply system, the supply system used shall be that which provides a worst-case test condition, or tests shall be done in both configurations.
- e) Over-current Protection: The supply source shall be provided with the external over-current protection that will be present in the intended installation, as specified in 5.3.25.3.2.2. This protection shall not operate during any tests in normal conditions, but is allowed to operate to protect the system during tests in single fault conditions.
- f) Prospective short-circuit current: Where the results of a test could be affected, the short-circuit current sourcing capability of the supply source shall be taken into consideration. Where high prospective short-circuit current is considered to be the worst-case test condition, the capability of the source shall not be less than the maximum prospective short-circuit current that part of the PCE is rated for in accordance with 5.3.2g). Where low prospective short-circuit current is worst case, a suitably limited source shall be used, taking into account any PCE specification regarding minimum required prospective short-circuit current.

NOTE For some fault tests, less than maximum short circuit current may be worst-case, for example if it results in longer test duration or where fuses are relied on to clear the fault and have minimum prospective short-circuit current requirements.

For a PCE port that is rated for having more than one source or types of sources of prospective short circuit current connected in parallel to it, the source used during testing shall provide prospective short-circuit current not less than the combined worst case taking into account all sources of prospective short-circuit current.

NOTE In the above context, the sources of prospective short circuit current may be sources of supply but may also be other paralleled equipment. Examples include a PCE DC input rated to have a PV array connected in parallel with an energy storage system, or an AC output port intended for connection to the AC grid with other PCE connected in parallel

4.2.2.6.2 PV input ports

4.2.2.6.2.1 General

The DC source(s) of supply connected to the PCE's PV input port(s) during testing shall be in accordance with 4.2.2.6.1 except as follows:

The DC source used may be a DC power supply, a PV simulator, or if adequate stability can be assured, a PV array.

In general for product safety testing it is not necessary to use a source that simulates the I-V characteristic of a PV array, but consideration should be given to the current characteristics of the DC source of supply used for testing. A PV array has a very low ratio of available fault current to operating current. A DC power supply without current limiting may expose the PCE to higher current during fault tests than a PV array would, resulting in over-testing. Even with current limiting, a DC power supply may not be able to limit the peak current available from its output capacitors, again impacting fault testing. On the other hand, for some tests it may be important to use a current limited source rather than a DC power supply, to avoid under-testing, as the tripping capability and trip time of overcurrent protective devices changes with available fault current and the current-limited case may be worst-case.

Where the results of a test could be affected, the DC source:

- shall provide prospective short-circuit current at the PCE PV port equal to the rated $I_{CP\ PV}$ +/- 2%, and

NOTE If agreed by the PCE manufacturer and the test body the short circuit capacity of the source may exceed $I_{CP\ PV}$ by more than 2%

- shall limit its output voltage to not more than the manufacturer's specified $U_{DC\ MAX}$ for the PCE, under normal and load step change conditions

4.2.2.6.2.2 Available power from the DC source:

Where required by specific tests in this document, the DC source shall be capable of providing input power to the PCE equal to the product of the maximum prospective short circuit current $I_{CP\ PV}$ and maximum DC input voltage $U_{DC\ MAX}$ so that the input power to the PCE is maximized for those tests.

In other cases it is not required to use a DC source capable of operating with both the PV source current and voltage at their maximum values at the same time. It is generally adequate to be able to supply the maximum power point voltage and current at the same time, to be able to supply $U_{DC\ MAX}$ at no-load, and to be able to supply $I_{CP\ PV}$ under short circuit conditions.

NOTE A key characteristic of PV arrays is the I-V curve: when maximum voltage is available, the available current is at a minimum, and when maximum current is available, the voltage is at a minimum. For some tests on some types of PCE, using a source capable of maximum current and voltage at the same time may be needed for adequate testing, but in other cases this could result in over-testing.

4.2.2.6.3 Limited Voltage and/or Current Inputs

Where a PCE is intended to be operated from an upstream PCE having a limited voltage or limited current DC output in accordance with 4.9, (e.g. the output of a DCU), testing shall be in

1018 accordance with 4.2.2.6.1 except the source used shall either be the intended upstream PCE(s)
1019 or source(s) that provide equivalent voltage and current characteristics.

1020 **4.2.2.7 Conditions of loading for output ports**

1021 Tests shall be performed under the least favourable loading conditions, within the rated range(s)
1022 for each port, considering voltage, frequency, polarity, earthing, load current and type, and any
1023 other normal condition, where these considerations could affect the outcome of the test. An AC
1024 output port shall be loaded with linear load(s) to obtain the maximum rated output active or
1025 apparent power or current, whichever is worst case.

1026 A DC output port other than a port intended for charging a battery or other energy storage
1027 technology, shall be loaded with resistive load(s) to obtain the maximum rated DC output power
1028 or current, whichever is worst case.

1029 A DC output port intended for charging a battery, shall be loaded with a battery, a resistive-
1030 capacitive network, or other DC load that simulates the load characteristics of the intended type
1031 and size of battery the PCE is rated for, if the test results could be affected.

1032 A DC output port intended for connection to an energy storage technology other than a battery
1033 shall be loaded with the intended energy storage device, a resistive-capacitive network, or other
1034 DC load that simulates the load characteristics of the intended type and size of energy storage
1035 device the PCE is rated for, if the test results could be affected.

1036 Unless otherwise specified in this standard, loading conditions are to be maintained for a length
1037 of time as follows:

- 1038 – for continuous operation ratings, until steady conditions are established, except that where
1039 the loading condition is only present when the PV array is operating (i.e. has irradiance) the
1040 test condition may be limited to 12 h at full power (to approximate a single solar day);
- 1041 – for intermittent operation ratings, cycling until steady conditions are established, using the
1042 rated "ON" and "OFF" periods;
- 1043 – for short-term operation ratings, for the rated operating time.

1044 **4.2.2.8 Earthing terminals**

1045 A protective conductor terminal, if provided, shall be connected to earth. A functional earth
1046 terminal shall be connected or not connected to earth, whichever is worst case. Earthing
1047 provisions during testing shall be in accordance with the PCE manufacturer's installation
1048 instructions.

1049 **4.2.2.9 Controls**

1050 Controls which the operator can adjust shall be set to any position except that

- 1051 a) mains selection devices shall be set to the correct value unless otherwise noted in this
1052 standard;
- 1053 b) combinations of settings shall not be made if they are prohibited by the manufacturer's
1054 instructions provided with the equipment.

1055 **4.3 Temperature testing**

1056 **4.3.1 General**

1057 This subclause specifies requirements intended to prevent hazards due to:

- 1058 – touchable parts exceeding safe temperatures; and

- 1059 – components, parts, insulation and plastic materials exceeding temperatures which may
1060 degrade safety-related electrical, mechanical, or other properties during normal use over
1061 the expected life of the equipment; and
- 1062 – structures and mounting surfaces exceeding temperatures which may degrade the
1063 materials over the expected life of the equipment.

1064 **4.3.2 Maximum temperatures**

1065 **4.3.2.1 General**

1066 Materials and components shall be selected so that under the most severe rated operating
1067 conditions, the temperatures do not exceed the temperature limits below.

1068 Compliance is verified by measuring temperatures under the reference test conditions given in
1069 4.2 and as follows, for each rated operating condition or mode of the PCE that could affect the
1070 resulting temperatures.

1071 Tests of equipment rated for use in ambient temperatures up to 50 °C may be conducted at any
1072 ambient temperature in the range given in 4.2.2.1, in which case the difference between the
1073 maximum rated ambient temperature and the actual test ambient is to be subtracted from or
1074 added to (as appropriate) the measured temperatures for comparison to the limits specified
1075 below.

1076 PCE rated for use in ambient temperatures more than 50 °C shall be tested at the maximum
1077 rated ambient temperature ± 5 °C. The difference between the maximum rated ambient
1078 temperature and the actual test ambient is to be subtracted from or added to (as appropriate)
1079 the measured temperatures for comparison to the limits specified below.

1080 The +5 °C tolerance around the target testing ambient shall not result in damage to the EUT or
1081 an unintended change of operating conditions (e.g. premature derating). In such cases the
1082 ambient temperature should be adjusted lower, to ensure operation is not affected, and the
1083 difference added to the data for comparison to the limits.

1084 When a test chamber is used to achieve a target ambient temperature, the characteristics of
1085 the chamber (air circulation, temperature uniformity, etc.) may affect the testing. Care should
1086 be taken to ensure that chamber air circulation does not cool the EUT, and that all parts of the
1087 EUT are at the target ambient temperature. The ambient temperature around the EUT may have
1088 to be measured at more than one location, taking care regarding heat from the EUT influencing
1089 the ambient measurement.

1090 PCE with different output ratings or with automatic derating for different ambient temperatures
1091 shall be tested under as many conditions as are necessary to record worst-case temperatures,
1092 including at least the maximum ambient before derating begins, and the maximum rated ambient
1093 with derating.

1094 During thermal testing within normal conditions, protective devices other than automatic output
1095 derating systems shall not operate.

1096 Temperatures are to be measured by thermocouples, except that for transformers, inductors,
1097 and other coils the change of resistance method may be used.

1098 Temperatures used for comparison to the limits shall be taken only after thermal stability has
1099 been reached, except for short-term ratings below. Thermal stability is considered to have been
1100 reached when the temperature measurements are no longer rising. Attention shall be paid to
1101 any instability of the ambient temperature as it will affect the temperatures under consideration.
1102 Minor variations in component temperatures caused by ambient temperature variations do not
1103 necessarily indicate that stability has not been reached.

NOTE 1 In many cases (e.g. thermal chambers) the ambient temperature will have cyclical positive and negative variation, which may be observed (with some time lag) in component temperatures. It may be helpful to monitor the component temperature rises above the measured actual ambient temperature.

For temperature testing of short-term ratings, the temperatures shall be measured at the end of the specified duration. The load or other conditions shall be adjusted to the short-term rating after reaching stability at full load, unless the short-term rating has specific starting conditions specified in the PCE ratings documentation. Where a short-term rating is specified as allowed to repeat (i.e. a duty cycle), testing shall continue for more than one cycle to see if subsequent cycles result in higher temperatures and to achieve stability.

NOTE 2 For example, a PCE could be rated for 120% of the rated continuous capability, limited to 10 minutes from a fully heated starting condition, and could have a different rating from a cold start. A duty cycle example would be a PCE rated for a repeated 115% condition for max 5 minutes per instance, provided the PCE is operated at continuous rated load or less for 20 minutes or more between repetitions.

Temperatures determined by the rise-of-resistance method shall use the formula

$$T_r = R_2/R_1 (k + t_1) - (k + t_2)$$

where

T_r is the temperature rise in °C above the final room temperature t_2

R_1 is the resistance of the coil at the beginning of the test

t_1 is the room temperature in °C at the beginning of the test

R_2 is the resistance of the coil at the end of the test

t_2 is the room temperature in °C at the end of the test

$k = 234,5$ for copper, $225,0$ for aluminum

For other materials the correct value for the constant “ k ” shall be used.

4.3.2.2 Limits for materials and components:

4.3.2.2.1 Coils:

For coils and their insulation systems, the temperature limits in Table 2 apply. The applicable limit for a given location is dependent on the method of measurement: surface thermocouples, embedded thermocouples, or rise-of-resistance method, as given in the table.

For insulation that is not part of a coil, see 4.3.2.2.2.

4.3.2.2.2 Components and materials other than coils:

For other components and materials the measured temperatures shall not exceed the lower of a) and b)

a) the limits in the applicable IEC component standards and

b) the component or material manufacturer's rated operating temperature

except if neither of the above exists, temperature limits are given in Table 3.

For b), if a component manufacturer only states an ambient temperature rating for a component, the ambient temperature around the component shall be measured at location(s) that analysis shows will provide the maximum local ambient temperature. Analysis shall take into account:

- the presence and direction of forced air cooling

- nearby heat-generating components

1145 - parts or materials of the component that are most likely affected by the ambient
1146 temperature

1147 For insulating materials that are not part of a coil as in 4.3.2.2.1 and are relied on for compliance
1148 with this document, the maximum temperature measured on the material shall not exceed the
1149 numerical value of the thermal class of the material (e.g. 90 C for “Class 90 C” material). This
1150 limit assumes that the thermocouple is located on the hottest part of the insulation under
1151 consideration. The limit shall be reduced to the value for surface mounted thermocouples in the
1152 second column of Table 2 if it is not possible to determine that the thermocouple is at the hottest
1153 location.

1154 **Table 2 – Total temperature limits for transformers, inductors,**
1155 **and other coils and their insulation systems**

Class of insulation (see IEC 60085)	Limits for surface mounted thermocouple measurements °C	Limits for resistance method and multiple embedded thermocouple measurements °C
Class A (105 °C)	90	95
Class E (120 °C)	105	110
Class B (130 °C)	110	120
Class F (155 °C)	130	140
Class H (180 °C)	150	160
Class N (200 °C)	165	175
Class R (220 °C)	180	190
Class S (240 °C)	195	205
NOTE Surface mounted thermocouples are assumed to not be located on the hot-spot, but will be typically attached to the core, coil, and insulation that is accessible on a completed part. Multiple embedded thermocouples, where the thermocouples are attached during winding of the part, are more likely to record hot-spot temperatures. The resistance method gives an average temperature for the specific winding whose resistance rise was measured.		

1156

1157

Table 3 – Total temperature limits for materials and components where manufacturer's ratings and component standards do not exist (see 4.3.2.2.2)

Materials and components	Limit °C
Capacitors - electrolytic types	65
Capacitors - other than electrolytic types	90
Wiring terminals for external (field wiring) connections ¹	60
Any point on or within a wiring compartment which external conductors are able to contact ¹	60
Insulated conductors internal to the PCE	rated temperature of the conductor insulation
Fuses	90
Printed circuit boards	105
Insulating materials	per 4.3.2.2.2
¹ The temperature observed on the terminals and at points within a terminal box or wiring component of a unit may exceed the values specified if the marking of 5.1.9 requires wiring of a suitably high temperature rating. In this case, measured temperatures on the terminals and wiring compartment are limited to the temperature rating of the wiring required by the marking.	

4.3.2.3 Limits for touch temperatures

In order to limit the touch temperatures of accessible parts of PCE, the maximum temperature for accessible parts of the PCE shall be in compliance with **Error! Reference source not found.**

It is permitted that accessible parts that are required to get hot as part of their intended function (for example heatsinks) may have temperatures up to 100 °C, if the parts are marked with the hot surface marking of symbol 14 of Annex C.

These limits are in addition to the applicable limits in 4.3.2.2.

Table 4 – Total touch temperature limits for accessible surfaces

Part	Limit °C		
	Metal	Glass, porcelain, and other vitreous material ^a	Plastic and rubber ^a
Devices (knobs, handles, switches, displays, etc.) which are continuously held by the operator in normal use	55	65	75
Devices (knobs, handles, switches, displays, etc.) which are held by the operator for short periods only in normal use	60	70	85
Enclosure parts accessible to casual contact by the operator.	70	80	95
^a Non-metallic materials shall not be used above their temperature ratings.			

Compliance is checked by the testing in 4.3.2.1.

4.3.2.4 Temperature limits for mounting surfaces

In order to protect against long-term degradation of building materials, surfaces of the PCE that will be in contact with the mounting surface shall not exceed a maximum total temperature of 90 °C, except for PCE specified as not intended for mounting on combustible materials in accordance with 5.3.2.1.

This limit is in addition to the applicable limits in 4.3.2.1 through 4.3.2.3.

Compliance is checked by the testing in 4.3.2.1 with the PCE mounted according to the manufacturer's instructions, on a softwood surface.

4.4 Testing in single fault condition

4.4.1 General

Testing in single fault condition is done to determine that no hazards result from reasonably expected fault conditions that may arise in normal service or from reasonably expected misuse.

Fault testing shall be done unless it can be conclusively demonstrated that no hazards could arise from a particular fault condition, or unless alternative methods of checking compliance are specified in this standard in place of fault testing.

Compliance is checked by applying the criteria of 4.4.3 after each of the tests specified in 4.4.4 under the conditions specified in 4.4.2.

4.4.2 Test conditions and duration for testing under fault conditions

4.4.2.1 General

These requirements apply to testing in accordance with 4.4, and to any other clause of this document that specifies testing under fault conditions.

The equipment shall be operated under the combination of reference test conditions in 4.2, which is worst case for the particular fault test being performed.

When configuring sources for fault testing, consideration shall be given to the fact that for some fault tests, a source limited to less than the maximum rated current or power of that input of the PCE may be more severe than if a maximum rated current source was used. Test duration may be longer, and heating in the fault path may be more severe under limited conditions. For example on a PV input, it may be more severe to test with a DC source limited to less than $I_{CP\ PV}$.

Fault conditions shall be applied only one at a time and shall be applied in turn in any convenient order. Unless specified elsewhere for a specific test, more than one fault shall not be applied simultaneously. Where a subsequent fault arises as a consequence of an applied fault that shall be considered a single fault. Separate samples of the EUT may be used for each separate fault test applied, or the same sample may be used for many tests if damage from previous fault tests has been repaired or will not affect the results of further tests.

If a PCE circuit or component is used more than once in the design, it is not required to repeat the same fault test(s) on all occurrences, if the results of testing one are representative of the other(s) (for example where a PCE has multiple PV string inputs each with the same design).

Faults shall be applied using a switching device connected to the terminals of the component or port under test, in parallel or series as needed to simulate short circuiting or opening of the component. Conductors used shall be as short as possible and of a cross-section approximately equal to that of the component leads. For faults applied to ports for external circuits, the conductors used shall be the largest conductor size that is specified for use with that port in the

1215 installation instructions. The switching device for a short-circuit test shall be of adequate
1216 current-carrying capacity and low enough impedance (relative to the conductors) to not
1217 significantly limit the current flow.

1218 **4.4.2.2 Duration of tests**

1219 The equipment shall be operated until further change as a result of the applied fault is unlikely,
1220 as determined by (for example) opening of a device that removes the influence of the fault,
1221 stabilization of temperatures, etc.

1222 If a non-resettable, manual, or automatically resetting protective device or circuit operates in
1223 such a way as to interrupt or mitigate the fault condition, the test duration is as follows:

- 1224 – automatic reset devices or circuits: allow the protection to cycle on and off until no further
1225 change as a result of the applied fault is likely, until the ultimate result is obtained, or
1226 until temperatures stabilize;
- 1227 – manual reset devices or circuits: three cycles, with the device or circuit reset as soon as
1228 possible after tripping;
- 1229 – non-resettable devices or circuits: one cycle.

1230 **4.4.3 Pass/fail criteria for testing under fault conditions**

1231 **4.4.3.1 General**

1232 It is not required that PCE remain undamaged following any fault test in 4.4. Damage to the
1233 PCE is acceptable as long as the criteria in this clause are complied with.

1234 **4.4.3.2 Protection against shock hazard**

1235 Compliance with requirements for protection against electric shock is checked during and after
1236 the application of single faults as follows:

- 1237 a) by making measurements to check that no accessible DVC A circuits or exposed-conductive
1238 parts have become shock-hazardous using the steady state limits for DVC A in Table 7 and
1239 the short-term limits of 0,. Compliance is checked by monitoring accessible DVC A circuits
1240 and accessible conductive parts during and after each single fault test, and by the testing in
1241 c);;
- 1242 b) by confirming by analysis or test that the protection provided by protective impedance or
1243 protective voltage limitation in accordance with 7.3.5.3 or 7.3.5.4 is maintained
- 1244 c) by performing a dielectric strength test as per 7.5.2 (without humidity preconditioning) in the
1245 following cases:
 - 1246 i) on reinforced or double insulation, protective impedance networks, and protective
1247 voltage limitation networks, using the test level for basic insulation, and
 - 1248 ii) on basic insulation in protective class I equipment, using the test level for basic
1249 insulation, unless it can be determined that the fault did not result in any damage to
1250 the protective earthing conductor or terminal, or to protective bonding means; and
- 1251 d) by inspection of the enclosure to ensure that no damage has resulted that allows the test
1252 probe of Figure D.1 to contact bare or functionally insulated hazardous live parts.

1253 **4.4.3.3 Protection against the spread of fire**

1254 Compliance with requirements for protection against the spread of fire is checked by placing
1255 the equipment on tissue paper covering a softwood surface and covering the equipment with
1256 cheesecloth during the fault testing. For wall-mounted PCE with openings on the PCE mounting
1257 surface, the cheesecloth shall also be located between the PCE and the mounting surface.

1258 As an alternative for large equipment, the cheesecloth may be placed only over the openings
1259 in the enclosure

1260 There shall be no emission of molten metal, burning insulation, or flaming or glowing particles
1261 from the fire enclosure, and there shall be no charring, glowing, or flaming of the tissue paper
1262 or cheesecloth..

1263 For floor-mounted equipment rated only for mounting on non-combustible materials in
1264 accordance with 0 and 5.3.2.1, the requirement to mount the equipment on tissue paper
1265 covering a softwood surface does not apply.

1266 Cheesecloth used shall be cotton, running approx. 26 - 28 m²/kg (14 - 15 yd²/lb.) with a count
1267 of approx. 12.6 x 11 threads per cm (32 x 28 threads per inch (also known as Grade #60)).

1268 Tissue paper used shall be wrapping tissue with a mass per unit area of approx. 12 - 30 g/m².

1269 4.4.3.4 Protection against other hazards

1270 During and after the fault tests, there shall be no damage to the enclosure that allows the test
1271 probe of Figure D.1 to contact mechanical hazards such as moving parts.

1272 Compliance with requirements for protection against other hazards after application of the fault
1273 tests is checked as specified elsewhere in this standard.

1274 4.4.3.5 Protection against parts expulsion hazards

1275 Failure of any component within the PCE shall not release parts outside the PCE enclosure with
1276 sufficient energy to lead to a hazard, for example, expulsion of material into an area occupied
1277 by personnel. Compliance is checked in accordance with 8.6.

1278 4.4.4 Single fault conditions to be applied

1279 4.4.4.1 Component fault tests

1280 Circuit analysis shall be performed to identify components (including insulation systems) whose
1281 failure would result in a fire or electric shock or energy hazards. The analysis shall include the
1282 effect of short-circuit and open-circuit conditions of the component. Based on the analysis, faults
1283 shall be applied to relevant components in a manner that simulates the manner in which faults
1284 would occur in use. Components need only be faulted in a single mode (short-circuit or open-
1285 circuit), unless they do not have a predominant mode of failure.

1286 The PCE shall be operating before application of the fault, unless analysis shows that starting
1287 operation with the fault already applied will result in worst-case testing. The following faults
1288 shall be applied:

- 1289 a) Short circuit or open circuit of relevant components determined by the analysis above.
- 1290 b) Short circuit or open circuit of any components or insulation where failure could adversely
1291 affect supplementary insulation or reinforced insulation.
- 1292 c) In addition, where required by Method 2 of 9.1.1, components that could result in a fire
1293 hazard are to be overloaded by applying single faults to internal components in the circuit
1294 under consideration, unless:
- 1295 - they comply with the requirements of 9.1.3, or
- 1296 - the components are not exposed to overload conditions as determined by analysis,
1297 considering single faults on components in the connected circuits.
- 1298 d) Faults to components where failure could adversely affect the protection provided by
1299 protective impedance or protective voltage limitation in accordance with 7.3.5.3 or 7.3.5.4

1300 NOTE 1 An overload condition is any condition between normal load and maximum current condition up to short
1301 circuit.

1302 NOTE2 The component fault testing does not need to include components for which equivalent testing is
1303 accomplished during other fault tests, such as output short-circuit tests.

1304 **4.4.4.2 Equipment or parts for short-term or intermittent operation**

1305 Components such as motors, relays, other electromagnetic devices and heaters, which are
1306 normally operated only intermittently, shall be operated continuously if continuous operation
1307 could occur in a single fault condition.

1308 **4.4.4.3 Motors**

1309 Motors shall be stopped while fully energized or prevented from starting, whichever is less
1310 favourable.

1311 **4.4.4.4 Transformer short circuit tests**

1312 The output windings of transformers shall be short-circuited one at a time, unless the
1313 transformer supplies only internal circuits and analysis shows that failure of the transformer will
1314 not create a hazard.

1315 A transformer damaged during one test may be repaired or replaced before the next test.

1316 **4.4.4.5 Output port short circuit and PCE short circuit contribution**

1317 **4.4.4.5.1 General:**

1318 This test applies to any port of the PCE that is a power output in one or more operating mode(s),
1319 and serves both as a single fault test, and to generate short circuit current contribution data for
1320 reporting in the installation documentation.

1321 For short circuit testing of output ports normally connected to an external source of energy (e.g.
1322 a utility interactive inverter AC output, or a battery charging output) the PCE short circuit
1323 contribution measurement shall exclude any contribution from the external source (for example,
1324 by appropriately locating the current transducer, or by configuring the test system such that the
1325 external energy source is disconnected at the same time the short circuit is applied).

1326 Each power output port of the PCE shall be tested one at a time, to simulate short circuits in
1327 the load or wiring. Overcurrent protection devices as provided in the PCE or as specified in the
1328 installation instructions, shall be fitted during the test. All other output ports are loaded or not
1329 loaded, whichever load condition of normal use is less favourable. The PCE shall be operating
1330 in the mode in which the port under test is an output.

1331 **4.4.4.5.2 Combinations to be tested:**

1332 Testing is required to be performed on the following combination of terminals for the port under
1333 consideration:

- 1334 – each combination of line to line;
- 1335 – each line to neutral or earth, unless there is no neutral conductor and no earth reference;
1336 testing to neutral versus to earth shall be selected based on the system configuration taking
1337 into account the presence or lack of a neutral, whether any conductor is intentionally
1338 earthed, and other relevant aspects, to determine worst-case testing; and
- 1339 – all lines together.

1340 Analysis may be used to reduce the number of combinations to be tested, for example where it
1341 can be shown that a particular combination will not result in any fault current, or where one
1342 combination is representative of another combination.

1343 **4.4.4.5.3 Number of tests:**

1344 For an AC port, five iterations shall be performed for each of the above combinations, unless a
1345 test results in the short circuit being applied within 15 degrees of the peak of the voltage

1346 waveform for the phase combination under test, in which case further iterations are not required
1347 for that combination.

1348 For a DC port one iteration shall be performed for each of the above combinations.

1349 **4.4.4.5.4 Test criteria and reporting**

1350 In addition to the requirements of 4.4.3, the short-circuit currents from the PCE are to be
1351 recorded and provided in the installation manual for the purpose of coordination of overcurrent
1352 protection of the external circuit conductors, in accordance with 5.3.2g).

1353 The value(s) to be recorded and to be provided with the PCE installation documentation are:

1354 a) for all ports tested: the peak current

1355 b) for all ports tested:

1356 – if interruption occurs: the duration of the short circuit from the time the short circuit is
1357 applied, until the time the short circuit current is interrupted by a protective device or
1358 other mechanism; in this case the value stated shall include the duration in seconds and
1359 the current in amps RMS calculated over that duration

1360 – if interruption does not occur, and the test results in a continuous non-zero value: the
1361 value stated shall be given as “continuous steady-state” current in amps RMS calculated
1362 over an appropriate period during the steady-state portion of the waveform (i.e. not
1363 including the peak or subsequent part of the waveform before it stabilizes); and

1364 c) for tested AC output ports: the RMS value calculated over a movable 3-cycle window selected to
1365 give the highest RMS result, stated as the 3-cycle RMS value; the 3-cycle calculation window width
1366 shall be based on the nominal frequency of the AC port under test, and the starting time for the
1367 window shall be any time at or after the moment the short circuit is applied, selected to maximize the
1368 RMS result without regard for other events or features of the current waveform

1369 NOTE 1 See Annex K for examples

1370 NOTE 2 For example, the RMS calculation window used in c) can include the peak if that portion of the waveform
1371 results in the highest 3-cycle RMS value; in such a case, the above requires the peak value to also to be reported as
1372 in a)

1373 For the test in which all terminals (phases) are short circuited to each other, all phase currents
1374 shall be measured and the highest value from any phase shall be reported.

1375 It is recommended that this data is accompanied by sample waveforms in the PCE
1376 documentation, so that users of the data have a better understanding of the nature of the current
1377 waveforms.

1378

1379 **4.4.4.6 Backfeed current and PV reverse current test for PCE with more than one** 1380 **source of energy**

1381 **4.4.4.6.1 General**

1382 NOTE 1 Adequate information regarding backfeed and reverse currents is needed in order for the system designer
1383 to provide properly coordinated protection for conductors, PV modules and other equipment connected to the PV
1384 port(s) of the PCE.

1385 These requirements apply to the PV input port(s) where the PCE is connected to more than one
1386 source of energy, regardless of the direction of intentional energy flow. The requirements are
1387 intended to address risks associated with currents that may flow back out of the PCE onto a
1388 connected PV circuit or sub-array, driven by energy from other sources within or connected to
1389 the PCE, including parallel PV strings or sub-arrays. Examples and additional explanation can
1390 be found in Annex K.

These requirements address the following:

a) PCE Backfeed current - to qualify whether PCE backfeed current can flow into the PV port under consideration, and if so, to quantify it; PCE backfeed current is driven by energy sources within or connected to the PCE, other than:

- other PV ports if applicable (see PV reverse current below), and

- an external battery port if applicable (see External battery backfeed below).

Generally the sources of PCE backfeed are PCE input or output ports that are externally energized (e.g. an AC input, the AC output of a grid interactive inverter, or a DC output connected to a DC bus energized by other sources), or internal batteries or other energy storage used as sources for the power conversion. It is assumed that PCE ports connected only to passive loads are not a source of PCE backfeed current.

b) PV reverse current for PCE with more than 1 PV input port - to qualify whether any PV reverse current can flow out of the PCE onto the PV input port under consideration, driven by energy from the other PV input ports; PV reverse current is not quantified in this document, as it depends on installation-specific PV array design aspects; however the ability of the PCE to block PV reverse current may be evaluated.

c) External battery backfeed current - to qualify whether any backfeed current can flow into the PV input port under consideration, driven by energy from an external battery (for a PCE with an external battery port); external battery backfeed current is not quantified, as it depends on installation-specific battery and battery protection design aspects. However the ability of the PCE to block external battery backfeed current may be evaluated. Conversely, backfeed current from internal batteries is included in a) above.

d) Abnormal testing - to determine if the PCE remains safe, in accordance with the pass/fail criteria of 4.4.3, during and following application of a short circuit to the PV input port(s) under consideration

NOTE 2 These requirements consider backfeed and PV reverse current scenarios that can occur after the installation is put in service, such as a short circuit between conductors. Faults that can occur during installation, such as connecting a PV string with reverse voltage polarity, are not considered as they are assumed to have been detected during commissioning and corrected before energizing the PCE.

Quantifying the PCE backfeed current in a) is intended to provide data for the PCE documentation in accordance with 5.3.2.2 h) regarding the RMS backfeed current available (if any) and its duration, to aid the system designer in selection of conductor sizes and overcurrent (overload) protection and in coordination with PV module maximum reverse current rating.

The PCE backfeed current may be reported as zero if analysis determines that the current 1 s after application of the fault does not exceed 100 mA.

NOTE 3 Shorter term backfeed current is not considered likely to cause overheating of conductors, PV modules, and other equipment. The allowance for 100mA is intended to provide for small leakage currents (for example the current that remains when a semiconductor is in its off state).

Qualifying whether or not the PCE topology blocks or allows any of these types of reverse/backfeed current is intended to provide data for the PCE documentation in accordance with 5.3.2.2 i) and j) respectively. This information allows the installer to determine if these aspects affect the need for and selection of overcurrent protection devices or sizing of conductors when applying applicable installation standards. The information is also needed in determining the scope of analysis and testing in 4.4.4.6.7.

The PCE backfeed current test of 4.4.4.6.3 only measures and reports contributions from the sources in a) above. The backfeed current measured in that test does not include PV reverse current or external battery backfeed current as the contribution from those sources depends on specific installation details such as array size, battery characteristics, overcurrent protection, etc.

1440 NOTE 4 The above exclusions are a significant change from Ed. 1 of this document, in which all sources of backfeed
1441 and PV reverse current were energized during the testing, and were therefore included in the measured and reported
1442 current. This change aligns this 2nd Edition of IEC 62109-1 with the 2nd Edition of the installation standard IEC 62548
1443 (in preparation at the time of this IEC 62109-1 draft). Regarding the 3rd Edition of IEC 60364-7-712 (in preparation at
1444 the time of this IEC 62109-1 draft) it also anticipates the PCE backfeed current rating to not include the PV reverse
1445 current.

1446 The additional PCE backfeed current test of 4.4.4.6.4 is performed with all sources connected
1447 to the PCE, to establish worst-case conditions for a single-fault test, and is not used for reporting
1448 values.

1449 **4.4.4.6.2 Use of analysis**

1450 Analysis of the design may be used as follows:

- 1451 a) to determine which operating mode(s) will provide worst case results for each port;
- 1452 b) to determine whether testing one port or one pair of conductors of a multi-conductor port is
1453 representative of other ports or other combinations of conductors; and
- 1454 c) to determine whether the backfeed current reported according to 5.3.2.2h) can be
1455 determined to be zero without test, in which case testing in accordance with 4.4.4.6.3 is not
1456 required; for the purposes of this analysis, backfeed current may be reported as zero if
1457 analysis determines that the current 1 s after application of the fault does not exceed 100
1458 mA.

1459 This analysis shall not be used in lieu of the testing of 4.4.4.6.3 to determine the event duration
1460 and RMS value over the duration, except where c) above shows a result supporting a reported
1461 PCE backfeed current value of zero. The analysis option is intended to reduce the amount of
1462 testing.

1463 For the testing in 4.4.4.6.4 the analysis may be used to reduce, but not completely eliminate,
1464 the testing.

1465 **4.4.4.6.3 Test procedure for obtaining PCE backfeed current reporting values**

1466 This test provides the data for backfeed current value reporting in accordance with 5.3.2.2h),
1467 and shall be performed on each PV input port except in accordance with 4.4.4.6.2. Compliance
1468 with 4.4.3 shall also be verified.

1469 NOTE The test in 4.4.4.6.4 also checks compliance with 4.4.3 but under different test conditions, and is unrelated
1470 to backfeed current reporting. The conditions for the reporting test in 4.4.4.6.3 are not worst-case from the
1471 perspective of ensuring single-fault safety of the PCE as covered by the testing of 4.4.4.6.4.

1472 The PCE shall be operated with the PV input port under test and all other ports energized,
1473 except for:

- 1474 – PV ports other than the port under test if applicable, and
- 1475 – an external battery port if applicable

1476 If the PCE is not able to operate normally (before application of the fault) with the other PV
1477 ports or external battery not energized, then the port(s) preventing operation shall be energized
1478 for the test. In this case, the test setup or measurements shall be arranged such that energizing
1479 of these ports does not affect the reported value. Either:

- 1480 a) the current contribution from these ports during the test shall be measured and subtracted
1481 from the reported result; or
- 1482 b) the test setup shall be such that significant current contribution to the resulting backfeed
1483 current measurement under test is prevented; modification of the EUT to prevent backfeed
1484 contribution from these ports is acceptable if the modification does not affect the PCE
1485 backfeed current contribution from the intended sources.

1486 Overcurrent protective devices normally present in the installation or required by the PCE
1487 installation instructions, shall be connected.

1488 Internal batteries and internal energy storage capable of contributing to the PCE backfeed
1489 current shall be at the maximum charge level they would be at under normal operating
1490 conditions.

1491 With the PCE operating as above, a short circuit shall be applied at the field wiring terminals of
1492 the PV input port under consideration and the PCE backfeed current through the shorting device
1493 shall be measured.

1494 The test shall be performed with the shorting device connected line to line. For PCE for use
1495 with, or providing, functional earthing of the PV array, tests from line to earth shall be considered
1496 and tested if the result may be worst case. If the PV input is bipolar or has more than one circuit
1497 connected, additional combinations of lines shall be considered. Analysis according to 4.4.4.6.2
1498 shall be used to determine the combinations to be tested.

1499 One iteration of the test shall be performed for each selected combination of lines.

1500 In addition to the pass/fail criteria of 4.4.3, the backfeed current measured through the shorting
1501 device shall be measured and provided in the installation manual in accordance with 5.3.2.2h).

1502 The values to be reported are as in 4.4.4.5.4 b).

1503 For the purposes of these requirements, backfeed current may be reported as zero if the current
1504 measured 1 s after application of the fault does not exceed 100 mA.

1505 Where the PCE backfeed current is prevented by electronic devices or networks, the
1506 requirements of 4.4.4.6.7 apply.

1507 **4.4.4.6.4 PCE backfeed current test procedure under worst case fault conditions**

1508 This procedure is in addition to that in 4.4.4.6.3, and is intended to show compliance with 4.4.3
1509 with all external sources energized, as a worst case single fault test. Results from this test are
1510 not used for backfeed current value reporting.

1511 The PCE shall be operated under normal conditions, with all intended sources connected to the
1512 PCE and energized in accordance with 4.4.2.

1513 Overcurrent protective devices normally present in the installation or required by the PCE
1514 installation instructions, shall be connected.

1515 All internal and external batteries or other energy storage sources of backfeed current shall be
1516 at the maximum charge level they would be at under normal operating conditions.

1517 With the PCE operating as above, a short circuit shall be applied at the field wiring terminals of
1518 the PV input port under consideration.

1519 The test shall be performed line to line on the PV input port under consideration unless other
1520 combinations may be worst case. Analysis may be used as in 4.4.4.6.2 b) to reduce the number
1521 of tests performed.

1522 One iteration of the test shall be performed for each selected combination of lines.

1523 The PCE shall comply with the criteria of 4.4.3.