UL 62109-1

STANDARD FOR SAFETY

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

UL Standard for Safety for Safety of power converters for use in photovoltaic power systems – Part 1: General requirements, UL 62109-1

First Edition, Dated July 18, 2014

Summary of Topics

This revision of ANSI/UL 62109-1 dated April 30, 2019 is being issued to update the title page to reflect the most recent designation as a Reaffirmed American National Standard (ANS).

Please note that the national difference document incorporates all of the U.S. national differences for UL 62109-1.

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin.

The requirements are substantially in accordance with Proposal(s) on this subject dated February 22, 2019.

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UL 62109-1

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

First Edition

July 18, 2014

This ANSI/UL Standard for Safety consists of the First Edition including revisions through April 30, 2019.

The most recent designation of ANSI/UL 62109-1 as a Reaffirmed American National Standard (ANS) occurred on April 30, 2019. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, or Preface. The National Difference Page and IEC Foreword are also excluded from the ANSI approval of IEC-based standards.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at https://csds.ul.com.

No Text on This Page

CONTENTS

Annex F (informative) Altitude correction for clearances

Annex G (informative) Clearance and creepage distance determination for frequencies greater than 30 kHz

Annex H (informative) Measuring instrument for touch current measurements

Annex I (informative) Examples of protection, insulation, and overvoltage category requirements for PCE

Annex J (normative) Ultraviolet light conditioning test

Annex DVA (informative) Standards for Components (See 14.1DV)

Preface (UL)

This UL Standard is based on IEC Publication 62109-1: First edition Standards for Safety of power converters for use in photovoltaic power systems – Part 1: General requirements. IEC publication 62109-1 is copyrighted by the IEC.

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Note – Although the intended primary application of this Standard is stated in its Scope, it is important to note that it remains the responsibility of the users of the Standard to judge its suitability for their particular purpose.

NATIONAL DIFFERENCES

There are five types of National Differences as noted below. The difference type is noted on the first line of the National Difference in the standard. The standard may not include all types of these National Differences.

DR – These are National Differences based on the **national regulatory requirements**.

D1 – These are National Differences which are based on **basic safety principles and requirements**, elimination of which would compromise safety for consumers and users of products.

D2 – These are National Differences from IEC requirements based on existing **safety practices**. These requirements reflect national safety practices, where empirical substantiation (for the IEC or national requirement) is not available or the text has not been included in the IEC standard. |

DC – These are National Differences based on the **component standards** and will not be deleted until a particular component standard is harmonized with the IEC component standard.

DE – These are National Differences based on **editorial comments or corrections**.

Each national difference contains a description of what the national difference entails. Typically one of the following words is used to explain how the text of the national difference is to be applied to the base IEC text:

Addition / Add - An addition entails adding a complete new numbered clause, subclause, table, figure, or annex. Addition is not meant to include adding select words to the base IEC text.

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Deletion / Delete - A deletion entails complete deletion of an entire numbered clause, subclause, table, figure, or annex without any replacement text.

INTERNATIONAL ELECTROTECHNICAL COMMISSION

SAFETY OF POWER CONVERTERS FOR USE IN PHOTOVOLTAIC POWER SYSTEMS – Part 1: General requirements

FOREWORD

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International Standard IEC 62109-1 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

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

FDIS	Report on voting
82/593/FDIS	82/597/RVD

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

A list of all parts of IEC 62109 series, under the general title, *Safety of power converters for use in photovoltaic power systems*, 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 ″http://webstore.iec.ch″ in the data related to the specific publication. At this date, the publication will be

• reconfirmed,

• withdrawn,

• replaced by a revised edition, or

• amended.

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

1DV DE *Addition:*

Add the following to the end of the Foreword:

The numbering system in the standard uses a space instead of a comma to indicate thousands and uses a comma instead of a period to indicate a decimal point. For example, 1 000 means 1,000 and 1,01 means 1.01.

INTRODUCTION

This Part 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 standard which must be read in conjunction with the Part 1 requirements.

SAFETY OF POWER CONVERTERS FOR USE IN PHOTOVOLTAIC POWER SYSTEMS – Part 1: General Requirements

1 Scope and object

1.1 Scope

This part of IEC 62109 applies to the 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.

This standard provides general requirements applicable to all types of PV PCE. There are additional parts of this standard that provide specific requirements for the different types of power converters, such as Part 2 – inverters. Additional parts may be published as new products and technologies are commercialised.

1.1.1 Equipment included in scope

This standard covers PCE connected to systems not exceeding maximum PV source circuit voltage of 1 500 V d.c. The equipment may also be connected to systems not exceeding 1 000 V a.c. at the a.c. mains circuits, non-mains a.c. load circuits, and to other DC source or load circuits such as batteries. This standard may be used for accessories for use with PCE, except where more appropriate standards exist.

Evaluation of PCE to this standard includes evaluation of all features and functions incorporated in or available for the PCE, or referred to in the documentation provided with the PCE, if such features or functions can affect compliance with the requirements of this standard.

1.1.1DV DR *Modification in accordance with the following:*

Replace the maximum PV source circuit voltage of 1 500 V d.c. with 2 000 V d.c.

1.1.2 Equipment for which other requirements may apply

This standard has not been written to address characteristics of power sources other than photovoltaic systems, such as wind turbines, fuel cells, rotating machine sources, etc.

NOTE 1 Requirements for other sources may be incorporated in the IEC 62109 series in the future.

Additional or other requirements are necessary for equipment intended for use in explosive atmospheres (see IEC 60079), aircraft, marine installations, electromedical applications (see IEC 60601) or at elevations above 2 000 m.

NOTE 2 Requirements are included for adjustment of clearance distances for higher elevations, but not for other factors related to elevation, such as thermal considerations

1.1.2DV DR *Modification in accordance with the following:*

Add new sentence before NOTE 1. ″PV PCE with inputs for other non-PV power sources (not specifically addressed by this standard), shall address the normal and abnormal source specific operating characteristics including but not limited to; voltage range, current range, short circuit current, over-voltage, etc.″

1.2 Object

1.2.1 Aspects included in scope

The purpose of the requirements of this part of IEC 62109 is to ensure that the design and methods of construction used 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 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.

1.2.2 Aspects excluded from scope

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

a) functional reliability, performance or other properties of the equipment not related to safety;

b) effectiveness of transport packaging;

c) EMC requirements;

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

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

2 Normative references

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

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

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 60216-1, *Electrical insulating materials – Properties of thermal endurance – Part 1: Ageing procedures and evaluation of test results*

IEC 60216-2, *Electrical insulating materials – Thermal endurance properties – Part 2: Determination of thermal endurance properties of electrical insulating materials – Choice of test criteria*

IEC 60216-3, *Electrical insulating materials – Thermal endurance properties – Part 3: Instructions for calculating thermal endurance characteristics*

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

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 60227-1:2007, *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V - Part 1: General requirements*

IEC 60245-1:2003, *Rubber insulated cables – Rated voltages up to and including 450/750 V – Part 1: General requirements*

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 60364-1:2005, *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 60417, *Graphical symbols for use on equipment*

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

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

IEC 60664 (all parts), *Insulation coordination for equipment within low-voltage systems*

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

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

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

IEC 60695-2-20, *Fire hazard testing – Part 2-20: Glowing/hot wire based test methods – Hotwire coil ignitability – Apparatus, test method and guidance*

IEC 60695-11-5, *Fire hazard testing – Part 11-5: Test flames – Needle-flame test method – Apparatus, confirmatory test arrangement and guidance*

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

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

IEC 60730-1:2010, *Automatic electrical controls for household and similar use – Part 1: General requirements*

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

IEC 60950-1:2005, *Information technology equipment – Safety – Part 1: General requirements*

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

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

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

IEC 62020, *Electrical accessories – Residual current monitors for household and similar uses (RCMs)*

ISO 178, *Plastics – Determination of flexural properties*

ISO 179 (all parts), *Plastics – Determination of Charpy impact properties*

ISO 180, *Plastics – Determination of Izod impact strength*

ISO 261, *ISO general purpose metric screw threads – General plan*

ISO 262, *ISO general purpose metric screw threads – Selected sizes for screws, bolts and nuts*

ISO 527 (all parts), *Plastics – Determination of tensile properties*

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

ISO 4892-1, *Plastics – Methods of exposure to laboratory light sources – Part 1: General guidance*

ISO 4892-2, *Plastics – Methods of exposure to laboratory light sources – Part 2: Xenon-arc lamps*

ISO 4892-4, *Plastics – Methods of exposure to laboratory light sources – Part 4: Open-flame carbon-arc lamps*

ISO 7000, *Graphical symbols for use on equipment – Index and synopsis*

ISO 8256, *Plastics – Determination of tensile-impact strength*

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

ISO 9614-2, *Acoustics – Determination of sound power levels of noise sources using sound intensity – Part 2: Measurement by scanning*

ISO 9614-3, *Acoustics – Determination of sound power levels of noise sources using sound intensity – Part 3: Precision method for measurement by scanning*

ANSI/ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*

ANSI UL 746B, *Polymeric Materials – Long Term Property Evaluations*

ANSI UL 746C, *Polymeric Materials – Use in Electrical Equipment Evaluations*

ASTM E162, *Standard Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source*

2DV DC *Addition of the following:*

UL 50
Enclosures for Electrical Equipment

UL 67
Panelboards

UL 498
Attachment Plugs and Receptacles

UL 1741
Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources

UL 3703
Solar Trackers

UL 6703A
Outline of Investigation for Multi-Pole Connectors for Use in Photovoltaic Systems

UL 60730-1
Controls for Household and Similar Use, Part 1: General Requirements, Automatic Electrical and/or the applicable Part 2 standard from the UL 60730 series

UL 60950-1
Information Technology Equipment - Safety - Part 1: General Requirements

ANSI/NFPA 70
National Electrical Code

3 Terms and definitions

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

NOTE Unless otherwise specified, values of ″voltage″ and ″current″ are the r.m.s. values of an alternating, direct or composite voltage or current.

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

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

NOTE Basic insulation may serve also for functional purposes.

3.3 **battery type** the battery chemistry (e.g. lead-acid) and type (e.g. flooded, gel, etc.) or types of batteries intended for use with the PCE

3.4 **battery – sealed** a 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

3.5 **battery – non-sealed** a battery with removable caps or other provision for addition of water and/or electrolyte

3.6 **battery – valve regulated** a sealed battery with provision for the release of excessive pressure under abnormal conditions

3.7 **bipolar photovoltaic (PV) array** a photovoltaic array that consists of two interconnected arrays where one output connection of one array is connected to the opposite polarity output connection of the other array to create a common electrical node, similar to a centre-tapped transformer

3.8 **clearance** shortest distance in air between two conductive parts

3.9 **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

3.9DV DE *Modification in accordance with the following:*

Add ″(Restricted Access Location)″ after the term, ″closed electrical operating area″.

3.10 **comparative tracking index (CTI)** the 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

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

[IEV 151-03-37]

3.12 **decisive voltage** the decisive voltage of a circuit is the highest voltage which occurs continuously between any two arbitrary live parts of the PCE during worst-case rated operating conditions when used as intended (see Decisive Voltage Class limits in 7.3.2)

3.13 **decorative part** a part of the equipment, outside the enclosure, which has no safety function

3.14 **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

3.15 **double insulation** insulation comprising both basic insulation and supplementary insulation

[IEV 195-06-08]

3.16 **DVC A** decisive voltage classification (DVC) A as defined in 7.3.2

3.16DV DR *Modification by adding the following note:*

NOTE The limits for classification DVC A shown in Table 6 have been aligned with the relevant voltage limits in NFPA 70, Article 725, for Class 2 Circuits which are 42,4 Vpk or 60 Vdc in dry locations and 21,2 Vpk or 30 Vdc in wet areas.

3.17 **DVC B** decisive voltage classification (DVC) B as defined in 7.3.2

3.18 **DVC C** decisive voltage classification (DVC) C as defined in 7.3.2

3.19 **enclosure** a 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

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

3.21 **equipotential bonding** provision of electric connections between conductive parts, intended to achieve equipotentiality

[IEV 195-01-10]

NOTE The effectiveness of the equipotential bonding may depend on the frequency of the current in the bonding.

3.22 **equipotential bonding conductor** conductor electrically connecting metal parts to provide equipotential bonding

3.23 **EUT** equipment under test

3.24 **Extra Low Voltage (ELV)** voltage not exceeding the relevant voltage limit of band I specified in IEC 60449

[IEV 826-12-30]

NOTE 1 In IEC 60449 band I is defined as not exceeding 50 V a.c. r.m.s. and 120 V d.c.

NOTE 2 In this international standard, protection against electric shock is dependent on the decisive voltage classification.

3.24DV DR *Modification by replacing note 1 and note 2 with the following:*

NOTE In this international standard, protection against electric shock is dependent on the decisive voltage classification and we have aligned classification DVC A shown in Table 6 with the relevant voltage limits in NFPA 70, Article 725, for Class 2 Circuits which are 42,4 Vpk or 60 Vdc in dry locations and 21,2 Vpk or 30 Vdc in wet areas.

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

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

[IEV 826-07-07]

3.27 **flammability classification of materials** the recognition of the burning behaviour of materials and their ability to extinguish if ignited. Materials are classified as in the definitions in this standard, when tested in accordance with IEC 60695-11-10, IEC 60695-11-20, ISO 9772 or ISO 9773

NOTE 1 When applying the requirements in this standard, HF-1 class foamed materials are regarded as better than those of class HF-2, and HF-2 better than HBF.

NOTE 2 Similarly, other materials, including rigid (engineering structural) foam of class 5VA are regarded as better than those of class 5VB, 5VB better than V-0, V-0 better than V-1, V-1 better than V-2, V-2 better than HB40 and HB40 better than HB75.

NOTE 3 Similarly, other materials of class VTM-0 are regarded as better than those of class VTM-1 and VTM-1 better than VTM-2.

NOTE 4 Materials of flammability classes VTM-0, VTM-1 and VTM-2 are considered to be equivalent to materials of flammability classes V-0, V-1 and V-2, respectively, but only for their flammability properties. Their electrical and mechanical properties are not necessarily equivalent.

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

3.29 **functional insulation (FI)** insulation that is necessary only for the correct operation of the equipment

NOTE Functional insulation by definition does not protect against electric shock. It may, however, reduce the likelihood of ignition and fire.

3.30 **hand-held equipment** portable equipment intended to be supported by one hand during normal use

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

3.32 **hazardous energy level** an available power 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)

3.33 **hazardous live** capable of rendering an electric shock or electric burn. A circuit or a part that is either a shock or energy hazard as described in Clause 7

3.34 **hazardous voltage** a voltage exceeding the limits for shock hazard in 7.3

3.35 **homogeneous field (distribution)** a homogeneous field is an electric field which has an essentially constant voltage gradient between electrodes (uniform field), such as that between two spheres where the radius of each sphere is greater than the distance between them

3.36 **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

3.37 **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

3.38 **inhomogeneous distribution (of an electric field)** inhomogeneous distribution of an electric field refers to a field which does not have an essentially constant voltage gradient between electrodes (non-uniform field)

3.39 **Isc PV** absolute maximum total PV array short circuit current (d.c.) that the PCE is rated to have connected to its PV input, under worst-case conditions of ambient temperature, irradiance, etc.

NOTE This rating of the PCE refers to the absolute maximum current the PV input to the PCE is designed for under conditions of expected use. This differs from the simple sum of the marked Isc ratings of the connected PV modules, since those markings are based on short-circuit conditions under standard test conditions, and may be exceeded in cold temperatures or with irradiance above the standard level.

3.39DV DR *Modification by replacing the term and definition with the following:*

Isc MAX: absolute maximum prospective short circuit current (a.c. or d.c) that a port of the PCE is rated to have connected to it.

NOTE This could be the short circuit from a PV array, battery, energy storage device, generator or electric utility grid. For a PV source it would account for worst-case conditions of ambient temperature, irradiance, etc. For NEC compliant installation, this Maximum Input Short Circuit Current rating equates to 1,25 x Isc of the PV array.

3.40 **limited power source** a source complying with the requirements in 9.2 of this standard

3.41 **live parts** conductor or conductive part intended to be energized in normal use, including a neutral conductor

3.42 **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 a.c. or 1 500 V d.c.

3.42DV DE *Deletion*

Delete 3.42.

3.43 **mains** low-voltage a.c. electricity supply system to which the PCE is designed to be connected

3.43DV DR *Modification by replacing with the following:*

mains (AC Mains / AC supply connection): a.c. electricity supply system to which the PCE is designed to be connected

3.44 **mains circuit** circuit which is intended to be conductively connected to the mains

3.44.1DV DR *Modification by adding the following new term and definition:*

maximum voltage: The maximum voltage to which the PCE can be connected without damage. This may be indicated as a maximum voltage or voltage range.

NOTE The PCE is not required to operate normally at the maximum voltage or over the entire voltage range.

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

NOTE The terms earthed neutral and grounded conductor are also in common use. In this standard, the term neutral refers to any power circuit (mains, PV, battery, etc.) not just the mains.

3.46 **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

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

NOTE 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.

3.48 **operator** person operating equipment for its intended purpose

3.49 **operator access area** a 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, or

– 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.

3.50 **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

3.51 **overvoltage category (OVC)** numeral designation defining a classification of transient overvoltage conditions

[IEC 60664-1]

NOTE 1 See 7.3.7.1.2 for a description of the four overvoltage categories.

NOTE 2 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].

3.52 **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 (IEC 60664-1)

NOTE For a.c. tests the r.m.s. value may be used.

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

3.53DV DR *Modification by the adding the following to the end of the definition:*

"and electrically connected by means of a NEC-compliant permanently installed/fixed wiring system."

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

– under normal conditions and

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

NOTE PELV is the abbreviation for protective extra low voltage.

[IEV 826-12-32]

3.55 **photovoltaic (PV)** relating to the conversion of light directly into electrical energy

3.56 **photovoltaic (PV) array** an assembly of components such as photovoltaic panels, cables, connectors, combiners, etc., that produces and supplies d.c. electricity by the conversion of solar energy

3.57 **pluggable equipment type A** equipment which is intended for connection to the building installation wiring via a nonindustrial plug and socket-outlet or a non-industrial appliance coupler, or both

3.57DV DE *Modification by the adding the following note to the definition:*

NOTE NEMA configurations; 1-15, 2-15, 2-20, 5-15 and 5-20 plugs and outlets as specified in IEC 60083 are considered to be non-industrial within the meaning of this standard.

3.58 **pluggable equipment type B** equipment which is intended for connection to the building installation wiring via an industrial plug and socket-outlet or an appliance coupler, or both, complying with IEC 60309 or with a comparable national standard

NOTE PV circuits that use connectors are considered pluggable type B or fixed equipment.

3.58DV DR *Modification by the replacing the definition and note with the following:*

equipment which is intended for connection to the building installation wiring via an industrial plug and socket-outlet or an appliance coupler, or both, complying with IEC 60309 or with a comparable national standard. PV circuits that use connectors that require a tool to disconnect are considered pluggable type B.

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

3.60 **pollution degree** classification scheme describing the extent of expected pollution in a micro-environment in or around the equipment

3.61 **pollution degree 1** no pollution or only dry, non-conductive pollution occurs. The pollution has no influence

3.62 **pollution degree 2** normally only non-conductive pollution occurs. Occasionally, however, a temporary conductivity caused by condensation must be expected

3.63 **pollution degree 3** conductive pollution occurs, or dry, non-conductive pollution occurs which becomes conductive due to condensation which is expected

3.64 **port** location giving access to a device or network where electromagnetic energy or signals may be supplied or received or where the device or network variables may be observed or measured

3.65 **portable equipment** pluggable equipment intended to be moved from place to place

3.66 **power conversion equipment (PCE)** an 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 and frequency

NOTE Examples include AC-DC converters, DC-AC inverters, DC-DC charge controllers, frequency converters, etc.

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

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

3.69 **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

3.70 **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

3.71 **protective class III** equipment in which protection against electric shock relies upon supply from decisive voltage classification A circuits and in which hazardous voltages are not generated

NOTE For class III equipment, although there is no requirement for protection against electric shock, all other requirements of the standard apply.

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

3.72DV DR ***Modification by the replacing the glossary term with the following:***

protective earthing (equipment-grounding)

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

3.73DV DR ***Modification by the replacing the glossary term with the following:***

protective earthing (equipment-grounding) conductor

3.74 **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

3.74DV DR *Modification by the replacing the glossary term with the following:*

protective earthing (equipment-grounding) terminal

3.75 **protective impedance** component, assembly of components or the combination of basic insulation and a current or voltage-limiting device, whose impedance, construction and reliability are such that, when connected between accessible conductive parts and parts which are hazardous live, it provides protection to the extent required by this standard in normal condition and single fault condition

3.76 **protective separation** a construction means to maintain the separation between circuits of different protection levels even in the event of a single fault as described in 7.3.3

NOTE Protective separation is a separation between circuits by means of basic and supplementary protection (basic insulation plus supplementary insulation or protective screening) or by an equivalent protective provision (for example, reinforced insulation or protective impedance).

3.77 **rated** value assigned, generally by a manufacturer, to a specified operating condition of a component, device or equipment

[IEV 151-04-03]

3.78 **rating** set of rated values and operating conditions

[IEV 151-04-04]

3.79 **reference test conditions** the electrical, operating, and environmental conditions under which testing is to be performed, as specified in 4.2.2

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

NOTE A single insulation system does not imply that the insulation must be one homogeneous piece. It may comprise several layers which cannot be tested singly as basic or supplementary insulation.

3.81 **residual-current** vector sum of the currents flowing in the normally current carrying conductors of a mains circuit, expressed as an r.m.s. value

3.82 **responsible body** individual or group responsible for the use and maintenance of equipment and for ensuring that operators are adequately trained

3.83 **risk** a combination of the probability of the occurrence of harm and the severity of that harm

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

[IEV 151-04-16, modified]

3.85 **safety interlock** a means either of preventing access to a hazardous area until the hazard is removed, or of automatically removing the hazardous condition when access is gained

3.86 **sample test** tests on a number of devices taken at random from a production batch

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

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

– under normal conditions and

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

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

[IEV 826-12-31]

3.89 **service personnel** a person having appropriate technical training and experience necessary to be aware of hazards to which that person may be exposed in performing a task and of measures to minimize the risks to that person or other persons

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

[IEV 826-12-28]

3.91 **single fault condition** condition in which one means for protection against hazard is defective or one fault is present which could cause a hazard

NOTE If a single fault condition results in other subsequent failures, the set of failures is considered as one single fault condition.

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

3.92DV.1 DR *Addition of the following new term and definition:*

stabilized temperature: an operating condition where component temperatures are not changing. This condition is verified, by three successive temperature readings, taken at intervals of 10 percent of the previously elapsed duration of the test, and not less than 15 minutes apart, indicate no further increase in temperature. This term also covers variations of thermal stability or maximum temperature and is to be applied unless otherwise specified by requirements or parameters within a specific test method.

3.93 **terminal** a component provided for the connection of a device (equipment) to external conductors

[IEV 151-01-03, modified]

NOTE Terminals can contain one or several contacts and the term therefore includes sockets, connectors, etc.

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

3.95 **transportable equipment** equipment with a mass of less than 18 kg that is not fixed equipment and is intended to be routinely carried by a user

3.96 **type test** test of one or more samples (prototypes) of equipment (or parts of equipment) made to a particular design, to show that the design and construction meet one or more requirements of this standard

[IEV 151-04-15, modified]

NOTE This is an amplification of the IEV 151-04-15 definition to cover both design and construction requirements.

3.97 **Vmax PV** maximum rated d.c. input voltage the PCE is designed to withstand from the PV array (i.e. maximum open-circuit voltage) under worst-case conditions of ambient temperature, irradiance, etc.

3.97.1DV DR *Modification by adding the following new term and definition:*

voltage operating range: The input and/or output range of voltage over which the PCE is rated to operate including all modes of operation. If this parameter is adjustable, the maximum range of adjustment shall be included.

3.98 **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

3.99 **working voltage** voltage which occurs by design in a circuit or across insulation, when the PCE is operated under the worst case combination of highest and lowest rated voltages for each port, and under worst-case normal operating conditions. See 7.3.2.6

4 General testing requirements

4.1 General

Testing is required by this standard to demonstrate that the EUT is fully in accordance with the applicable requirements of this standard. This clause of this standard provides:

– 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 test 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.

To ensure that equipment will not become hazardous in expected humidity conditions, as specified in Table 4, 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.

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 favorable combination of the conditions given in 4.2.2.1 to 4.2.2.10. 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 favorable.

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 favorable.

4.2.2.6 Mains supply

Tests for which the outcome will not be significantly affected by the mains supply conditions, may be carried out at any rated supply conditions. For tests for which the outcome may be significantly affected by mains supply conditions, the test shall be performed at the worst-case mains 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 specifications for the EUT in which case the wider range is used. If the EUT will not operate across the full 90 % to 110 % range, the tolerance is taken as specified operating range. Testing under nominal supply conditions, or at supply conditions between the ends of the ranges, is only necessary if testing at the ends of the ranges is not worst-case.

b) Frequency: Multiple rated frequencies are to be taken into account (e.g. 50 Hz versus 60 Hz), but tolerances around these frequencies do not normally need to be considered.

c) Polarity: For 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: Inputs shall be provided with the over-current protection that will be present in the installation, and 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.

4.2.2.7 Supply ports other than the mains

Tests shall be performed at the least favorable combination of supply conditions, within the rated range(s) for each supply port, considering voltage, frequency, polarity, earthing, and any other normal condition, where these considerations could affect the outcome of the test.

Inputs shall be provided with the over-current protection that will be present in the installation, and 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.

For PV and battery inputs, the following additional requirements apply:

4.2.2.7.1 Photovoltaic supply sources

Where the results of a test could be affected by the voltage versus current characteristic of the supply, the PV source used shall simulate the voltage versus current characteristic of the largest PV array for which the equipment is rated, with regard to open circuit voltage (VMAX PV) and short-circuit current (Isc PV).

Tests performed under abnormal or fault conditions shall be tested with a source capable of 1,25 to 1,5 times the PCE rated maximum input current (Isc PV) for that input. If provided, any included or specified PCE overcurrent protective devices shall not be altered or changed.

NOTE When selecting test conditions for the PV supply, consideration has to be given to the characteristic of PV arrays: when maximum voltage is available, the available current is at a minimum, and when maximum current is available, the voltage is at a minimum. It is not expected that any test should be run with both the PV source current and voltage at their maximum values.

4.2.2.7.1DV DR *Modification by the replacing Photovoltaic supply sources, Clause 4.2.2.7.1, with the following:*

4.2.2.7.1DV.1 Where the results of a test could be affected by the voltage versus current characteristic of the supply, the PV source used shall simulate the voltage versus current characteristic of the largest PV array for which the equipment is rated, with regard to open circuit voltage (VMAX PV) and short-circuit current (Isc MAX). The input source shall not limit the operation of the PCE during normal operation testing. The supply shall be adjusted to operate within the PCE rated Input Voltage Operating Range.

4.2.2.7.1DV.2 Tests performed under abnormal or fault conditions shall be tested with a source capable of the PCE rated Maximum Input Source Short Circuit Current for that input (Isc MAX). If provided, any included or specified PCE overcurrent protective devices shall not be altered or changed.

NOTE When selecting test conditions for the PV supply, consideration has to be given to the characteristic of PV arrays: when maximum voltage is available, the available current is at a minimum, and when maximum current is available, the voltage is at a minimum. It is not expected that any test should be run with both the PV source current and voltage at their maximum values.

4.2.2.7.1DV.3 PCE connected to or specified for use with a specific source (with established electrical operating limits) may be tested with that specific source or a source that simulates the operating condition of that source.

4.2.2.7.2 Battery inputs

Battery inputs may be supplied from either a d.c. power supply or from a battery bank, except that for fault testing, where the magnitude of the available fault current could affect the results of the test, a battery bank of the size normally used with the product shall be used.

4.2.2.7.2DV DR *Modification by replacing with the following:*

Battery inputs may be supplied from either a d.c. power supply or from a battery bank, except that for fault testing, where the magnitude of the available fault current could affect the results of the test, a battery bank of the size, type and ratings defined in the product installation instructions shall be used.

4.2.2.8 Conditions of loading for output ports

Tests shall be performed under the least favorable loading conditions, within the rated range(s) for each port, considering voltage, frequency, polarity, earthing, load current and type, and any other normal condition, where these considerations could affect the outcome of the test. An a.c. output port shall be loaded with linear load(s) to obtain the maximum rated output power or current, whichever is least favourable. A d.c. output port (for example a battery charging output or a d.c. load port) shall be loaded with resistive load(s) to obtain the maximum rated output power or current, whichever is least favourable. For ports intended for connection to a battery, a battery shall be used in place of or in parallel with the load, if the test results could be affected.

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

– for continuous operation ratings, until steady conditions are established, except that for a test for which the only source of power is the PV input, testing is limited to 7 h at full power (to approximate a single solar day);

– for intermittent operation ratings, cycling until steady conditions are established, using the rated ″ON″ and ″OFF″ periods;

– for short-term operation ratings, for the rated operating time.

4.2.2.9 Earthing terminals

A protective conductor terminal, if provided, shall be connected to earth. A functional earth terminal shall be connected or not connected to earth, whichever is least favourable.

4.2.2.10 Controls

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

a) mains selection devices shall be set to the correct value unless otherwise noted in this standard;

b) combinations of settings shall not be made if they are prohibited by the manufacturer's instructions provided with the equipment.

4.2.2.11 Available short circuit current

Where the results of a test could be affected, the short circuit current sourcing capability of the source used during testing shall be taken into consideration. Where high available short circuit current is considered to be the worst-case test condition, the capability of the source shall not be less than the maximum short-circuit current the PCE is rated for.

NOTE For some tests, less than maximum short circuit current may be worst-case, if, for example, it results in longer test duration.

4.2.2.11DV DR *Modification in accordance with the following:*

Add ″(Isc Max) after ″short-circuit current″ in the last sentence.

4.3 Thermal testing

4.3.1 General

This subclause specifies requirements intended to prevent hazards due to:

– touchable parts exceeding safe temperatures; and

– components, parts, insulation and plastic materials exceeding temperatures which may degrade safety-related electrical, mechanical, or other properties during normal use over the expected life of the equipment; and

– structures and mounting surfaces exceeding temperatures which may degrade the materials over the expected life of the equipment.

4.3.2 Maximum temperatures

4.3.2.1 General

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

Compliance is verified by measuring temperatures under the conditions given in 4.2 for each rated operating condition or mode of the PCE that could affect the resulting temperatures.

The temperature limits specified below are total temperature limits (not temperature rise limits).

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

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

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

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

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

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

$$T = R2/R1 (k + t1) – (k + t2)$$

where

T is the temperature rise in °C

R1 is the resistance of the coil at the beginning of the test

t1 is the room temperature in °C at the beginning of the test

R2 is the resistance of the coil at the end of the test

t2 is the room temperature in °C at the end of the test

k = 234,5 for copper

k = 225,0 for aluminum

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

Limits:

– for coils and their insulation systems, the temperature limits in Table 1 apply

– for other components the measured temperatures shall not exceed the lower of:

– the limits in the applicable IEC component standards

– the component or material manufacturer's rated operating temperature

– if neither of the above exists, temperature limits are given in Table 2.

4.3.2.1DV DC *Modification of the last paragraph, second dash, in accordance with the following:*

Replace ″applicable IEC component standards″ with ″applicable component standards″.

Table 1 – Total temperature limits for transformers, inductors, 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.		

Table 2 – Total temperature limits for materials and components where manufacturer's ratings and component standards do not exist (see 4.3.2.1)

Materials and components	Limit °C
Capacitors – electrolytic types	65
Capacitors – other than electrolytic types	90
Wiring terminals for external 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
Fuses	90
Printed circuit boards	105
Insulating materials	90

[1] The temperature observed on the terminals and at points within a terminal box or wiring component of a unit is able to 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.

4.3.2.2 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 Table 3.

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. For products only for use in a closed electrical operating area the 100 °C limit does not apply.

These limits are in addition to the applicable limits in 4.3.2.1.

Table 3 – Total touch temperature limits for accessible surfaces

Part	Limit °C		
	Metal	Glass, porcelain, and other vitreous material[a]	Plastic and rubber[a]
User operated devices (knobs, handles, switches, displays, etc.) which are continuously held in normal use	55	65	75
User operated devices (knobs, handles, switches, displays, etc.) which are held for short periods only in normal use	60	70	85
Enclosure parts accessible to user by casual contact.	70	80	95

[a] Nonmetallic materials shall not be used above their temperature ratings.

Compliance is checked by the testing in 4.3.2.1.

4.3.2.3 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.

This limit is in addition to the applicable limits in 4.3.2.1 and 4.3.2.2.

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

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

NOTE 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 simulated array limited to less than Isc PV.

Fault conditions are to be applied only one at a time and shall be applied in turn in any convenient order. Multiple simultaneous faults shall not be applied, but a subsequent fault may arise as a consequence from an applied 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.

4.4.2.1DV DR *Modification by the replacing the note with the following:*

NOTE 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 simulated array limited to less than the value defined in 4.2.2.7.1.

4.4.2.2 Duration of tests

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

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

– automatic reset devices or circuits: allow the protection to cycle on and off until no further change as a result of the applied fault is likely, until the ultimate result is obtained, or until temperatures stabilize;

– manual reset devices or circuits: three cycles, with the device or circuit reset as soon as possible after tripping;

– non-resettable devices or circuits: one cycle.

4.4.2.2DV DR *Modification of the first paragraph in accordance with the following:*

Replace ″stabilization of″ with ″stabilized″.

4.4.3 Pass/fail criteria for testing under fault conditions

4.4.3.1 Protection against shock hazard

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

a) by making measurements to check that no accessible DVC-A circuits have become shock-hazardous using the steady state limits for DVC-A in Table 6 and the short-term limits of 7.3.2.3, and that such circuits remain separated from live parts at voltages greater than DVC A with at least basic insulation. Compliance is checked by the test of 7.5.2 (without humidity preconditioning) for basic insulation; and

b) by performing a dielectric strength test as per 7.5.2 (without humidity preconditioning) in the following cases:

i) on reinforced or double Insulation, using the test level for basic insulation, and

ii) on basic insulation in protective class I equipment, using the test level for basic insulation, unless it can be determined that the fault did not result in any damage to the protective earthing conductor or terminal, or to protective bonding means; and

c) by inspection to ensure a fuse connected between the protective earthing terminal and the protective earthing conductor in the test setup has not opened; the fuse shall be rated 3 A non-time-delay (for equipment rated for use on circuits protected by overcurrent protection rated 30 A or less) or 30 A to 35 A non-time-delay (for equipment rated for use on circuits protected by overcurrent protection rated more than 30 A); the enclosure is not to be contacting earth in any other location during the testing; and

d) by inspection of the enclosure to ensure that no damage has resulted that allows access to parts that are hazardous live.

4.4.3.1DV DR *Modification by the replacing part (c) with the following:*

c) by verification of i) or ii):

i) by inspection to ensure a fuse connected between the protective earthing terminal and the protective earthing conductor in the test setup has not opened; the fuse shall be rated 3 A non-time-delay (for equipment rated for use on circuits protected by overcurrent protection rated 30 A or less) or 30 A to 35 A non-time-delay (for equipment rated for use on circuits protected by overcurrent protection rated more than 30 A); the enclosure is not to be contacting earth in any other location during the testing, and d)

ii) by making measurements to check that no accessible parts become shock-hazardous using the steady state limits for DVC-A in Table 6 and the short-term limits of 7.3.2.3; and d).

4.4.3.2 Protection against the spread of fire

Compliance with requirements for protection against the spread of fire is checked by placing the equipment on white tissue-paper covering a softwood surface and covering the equipment with cheesecloth or surgical cotton during the fault testing. As an alternative, the cheesecloth or surgical cotton may be placed only over the openings of large equipment.

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

4.4.3.3 Protection against other hazards

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

4.4.3.4 Protection against parts expulsion hazards

Failure of any component within the PCE shall not release parts outside the PCE enclosure with sufficient energy to lead to a hazard, for example, expulsion of material into an area occupied by personnel.

4.4.4 Single fault conditions to be applied

4.4.4.1 Component fault tests

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

Faults shall be applied using a switching device connected to the terminals of the component or port under test. Conductors used shall be as short as possible and of a cross-section approximately equal to that of the component leads, or equal to the largest conductor size that is specified in the instructions to be used to connect to the port. The switching device for a short-circuit test shall be of adequate current-carrying capacity and low enough impedance (relative to the conductors) to not significantly limit the current flow.

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

NOTE 1 In some cases both tests may be required.

The following faults are simulated:

a) Short circuit or open circuit of relevant components.

b) Short circuit or open circuit of any components or insulation where failure could adversely affect supplementary insulation or reinforced insulation.

c) In addition, where required by Method 2 of 9.1.1, components that could result in a fire hazard are to be overloaded unless they comply with the requirements of 9.1.3.

NOTE 2 An overload condition is any condition between normal load and maximum current condition up to short circuit.

NOTE 3 The component fault testing does not need to include components for which equivalent testing is accomplished during other fault tests, such as output short-circuit tests.

4.4.4.1DV DR *Modification by replacing the first paragraph with the following:*

Circuit analysis shall be performed to identify components (including insulation systems) whose failure would result in a fire or electric shock hazard. The analysis shall include the effect of short-circuit and open-circuit conditions of the component. Based on the analysis, faults shall be applied to relevant components in a manner that simulates the manner in which faults would occur in use. Components need only be faulted in a single mode (short-circuit or open-circuit), to represent the component's predominant mode of failure. Components that can fail in either mode shall be tested for both fault conditions.

4.4.4.2 Equipment or parts for short-term or intermittent operation

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

4.4.4.3 Motors

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

4.4.4.4 Transformer short circuit tests

The output windings of transformers shall be short-circuited one at a time. A transformer damaged during one test may be repaired or replaced before the next test.

4.4.4.5 Output short circuit

Each power output port of the PCE, and each section of a tapped output, shall be tested one at a time, to simulate short circuits in the load or wiring. Overcurrent protection devices as provided in the PCE or as specified in the installation instructions, shall be fitted during the test. All other outputs are loaded or not loaded, whichever load condition of normal use is less favorable.

Testing is required to be performed on all combinations of terminals for the port under consideration, two at a time, including neutral and earth terminals, and one test with all current-carrying terminals of the port shorted together at once. Where analysis shows that the test for one combination is representative of other combinations, tests may be omitted.

In addition to the requirements of 4.4.3, the short-circuit currents are to be recorded and if they exceed the maximum rated current of the circuit, the maximum measured current shall be provided in the installation manual for the purpose of coordination of overcurrent protection of the external circuit conductors (see 5.3.2).

The value(s) to be recorded and to be provided with the PCE instructions are the peak current, and the highest of the RMS current values measured or calculated over a time period as follows:

a) for AC signals, 3 cycles of the nominal AC frequency for the port under consideration, in which case the value is to be stated as the 3-cycle RMS value;

b) for all signals, the duration of the short circuit from the time the short circuit is applied, until the time the short circuit current is interrupted by a protective device or other mechanism, in which case the value stated is to include the RMS value and the time period in seconds;

c) for short circuit tests that result in a continuous non-zero value, the steady-state RMS value, in which case the value is to be stated as a continuous RMS value.

NOTE Where the intended use of the short-circuit current information requires a different type of measurement, additional data may be provided. For example, for AC mains fault current contribution some utilities may prefer a 1/4-cycle RMS or other RMS calculation to the 3-cycle RMS above.

4.4.4.5DV D1 ***Modification by deleting the following text from the third paragraph:***

“and if they exceed the maximum rated current of the circuit”