SRI LANKA STANDARD 1543 PART 2 : 2016

IEC 62109 - 2 : 2011

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SPECIFICATION FOR

SAFETY OF POWER CONVERTERS FOR USE IN PHOTOVOLTAIC POWER SYSTEMS

PART 2 : PARTICULAR REQUIREMENTS FOR INVERTERS

SRI LANKA STANDARDS INSTITUTION

Sri Lanka Standard Specification for
SAFETY OF POWER CONVERTERS FOR USE IN PHOTOVOLTAIC POWER SYSTEMS
PART 2: PARTICULAR REQUIREMENTS FOR INVERTERS

SLS 1543 Part 2 : 2016
IEC 62109 - 2 : 2011

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Sri Lanka Standards are subject to periodical revision in order to accommodate the progress made by industry. Suggestions for improvement will be recorded and brought to the notice of the Committees to which the revisions are entrusted.

This standard does not purport to include all the necessary provisions of a contract.

Sri Lanka Standard Specification for
SAFETY OF POWER CONVERTERS FOR USE IN PHOTOVOLTAIC POWER SYSTEMS
PART 2: PARTICULAR REQUIREMENTS FOR INVERTERS

NATIONAL FOREWORD

This standard was approved by the Sectoral Committee on Electronic Engineering and was authorized for adoption and publication as a Sri Lanka Standard by the Council of Sri Lanka Standards Institution on 2016-11-24.

SLS 1543 Sri Lanka Standard Specification for Safety of power converters for use in photovoltaic power systems is published in two parts as follows:

Part 1: General requirements

Part 2: Particular requirements for inverters

This part of standard is identical with IEC 62109, Safety of power converters for use in photovoltaic power systems, Part 2: 2011 Edition 1.0 Particular requirements for inverters, published by the International Electrotechnical Commission (IEC).

All values given in this standard is in SI units.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or an analysis shall be rounded off in accordance with SLS 102, in case if the method of rounding off is not specified in the text of this standard. The number of figures to be retained in the rounded off value, shall be the same as that of the specified value in this standard.

Terminology and conventions

The text of the International Standard has been accepted as suitable for publication, without any deviation as a Sri Lanka Standard. However, certain terminology and conventions are not identical with those used in Sri Lanka Standards; attention is therefore drawn to the following:

a) Wherever the words “International Standard” appear referring to this standard they should be interpreted as “Sri Lanka Standard”.

b) Wherever the page numbers are quoted they are the page numbers of IEC standard.

c) The comma has been used as a decimal marker. In Sri Lanka Standards it is the current practices to use a full point on the base line as a decimal marker.

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CROSS REFERENCES

International Standards	Corresponding Sri Lanka Standards
IEC 60529, Degrees of protection provided by enclosures (IP Code)	SLS963, Classification for Degrees of protection provided by enclosures (IP Code)
ISO 178, Plastics – Determination of flexural properties	SLS ISO 178, Plastics – Determination of flexural properties
ISO 527 Plastics – Determination of tensile properties, Part 1 General Principles	SLS ISO 527 Plastics – Determination of tensile properties, Part 1 General Principles
ISO 527 Plastics – Determination of tensile properties, Part 2 test conditions for moulding and extrusion plastics	SLS ISO 527 Plastics – Determination of tensile properties, Part 2 test conditions for moulding and extrusion plastics

Any corresponding Sri Lanka Standard, for the international standards listed under reference, is not available.

SLS 1543-2:2016

IEC 62109-2

Edition 1.0 2011-06

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Safety of power converters for use in photovoltaic power systems –
Part 2: Particular requirements for inverters

Sécurité des convertisseurs de puissance utilisés dans les systèmes photovoltaïques –
Partie 2: Exigences particulières pour les onduleurs

IEC 62109-2:2011

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SAFETY OF POWER CONVERTERS FOR USE IN PHOTOVOLTAIC POWER SYSTEMS –

Part 2: Particular requirements for inverters

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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International Standard IEC 62109-2 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
82/636/FDIS	82/648A/RVD

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

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

The requirements in this Part 2 are to be used with the requirements in Part 1, and supplement or modify clauses in Part 1. When a particular clause or subclause of Part 1 is not mentioned in this Part 2, that clause of Part 1 applies. When this Part 2 contains clauses that add to, modify, or replace clauses in Part 1, the relevant text of Part 1 is to be applied with the required changes.

Subclauses, figures and tables additional to those in Part 1 are numbered in continuation of the sequence existing in Part 1.

All references to “Part 1” in this Part 2 shall be taken as dated references to IEC 62109-1:2010.

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.

INTRODUCTION

This Part 2 of IEC 62109 gives requirements for grid-interactive and stand-alone inverters. This equipment has potentially hazardous input sources and output circuits, internal components, and features and functions, which demand different requirements for safety than those given in Part 1 (IEC 62109-1:2010).

SAFETY OF POWER CONVERTERS FOR USE IN PHOTOVOLTAIC POWER SYSTEMS –

Part 2: Particular requirements for inverters

1 Scope and object

This clause of Part 1 is applicable with the following exception:

1.1 Scope

Addition:

This Part 2 of IEC 62109 covers the particular safety requirements relevant to d.c. to a.c. inverter products as well as products that have or perform inverter functions in addition to other functions, where the inverter is intended for use in photovoltaic power systems.

Inverters covered by this standard may be grid-interactive, stand-alone, or multiple mode inverters, may be supplied by single or multiple photovoltaic modules grouped in various array configurations, and may be intended for use in conjunction with batteries or other forms of energy storage.

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

NOTE Throughout this standard where terms such as “grid-interactive inverter” are used, the meaning is either a grid-interactive inverter or a grid-interactive operating mode of a multi-mode inverter

This standard does not address grid interconnection requirements for grid-interactive inverters.

NOTE The authors of this Part 2 did not think it would be appropriate or successful to attempt to put grid interconnection requirements into this standard, for the following reasons:

a) Grid interconnection standards typically contain both protection and power quality requirements, dealing with aspects such as disconnection under abnormal voltage or frequency conditions on the grid, protection against islanding, limitation of harmonic currents and d.c. injection, power factor, etc. Many of these aspects are power quality requirements that are beyond the scope of a product safety standard such as this.

b) At the time of writing there is inadequate consensus amongst regulators of grid-interactive inverters to lead to acceptance of harmonized interconnect requirements. For example, IEC 61727 gives grid interconnection requirements, but has not gained significant acceptance, and publication of EN 50438 required inclusion of country-specific deviations for a large number of countries.

c) The recently published IEC 62116 contains test methods for islanding protection.

This standard does contain safety requirements specific to grid-interactive inverters that are similar to the safety aspects of some existing national grid interconnection standards.

Users of this standard should be aware that in most jurisdictions allowing grid interconnection of inverters there are national or local requirements that must be met. Examples include EN 50438, IEEE 1547, DIN VDE 0126-1-1, and AS 4777.3

2 Normative references

This clause of Part 1 is applicable, with the following exception:

Addition

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

3 Terms and definitions

This clause of Part 1 is applicable, with the following exceptions:

Additional definitions

3.100
functionally grounded array
a PV array that has one conductor intentionally connected to earth for purposes other than safety, by means not complying with the requirements for protective bonding

NOTE 1 Such a system is not considered to be a grounded array – see 3.102.

NOTE 2 Examples of functional array grounding include grounding one conductor through an impedance, or only temporarily grounding the array for functional or performance reasons

NOTE 3 In an inverter intended for an un-grounded array, that uses a resistive measurement network to measure the array impedance to ground, that measurement network is not considered a form of functional grounding.

3.101
grid-interactive inverter
an inverter or inverter function intended to export power to the grid

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.

3.102
grounded array
a PV array that has one conductor intentionally connected to earth by means complying with the requirements for protective bonding

NOTE 1 The connection to earth of the mains circuit in a non-isolated inverter with an otherwise ungrounded array, does not create a grounded array. In this standard such a system is an ungrounded array because the inverter electronics are in the fault current path from the array to the mains grounding point, and are not considered to provide reliable grounding of the array

NOTE 2 This is not to be confused with protective earthing (equipment grounding) of the array frame

NOTE 3 In some local installation codes, grounded arrays are allowed or required to open the array connection to earth under ground-fault conditions on the array, to interrupt the fault current, temporarily ungrounding the array under fault conditions. This arrangement is still considered a grounded array in this standard.

3.103
indicate a fault
annunciate that a fault has occurred, in accordance with 13.9

3.104
inverter
electric energy converter that changes direct electric current to single-phase or polyphase alternating current

3.105
inverter backfeed current
the maximum current that can be impressed onto the PV array and its wiring from the inverter, under normal or single fault conditions

3.106
isolated inverter
an inverter with at least simple separation between the mains and PV circuits

NOTE 1 In an inverter with more than one external circuit, there may be isolation between some pairs of circuits and no isolation between others. For example, an inverter with PV, battery, and mains circuits may provide isolation between the mains circuit and the PV circuit, but no isolation between the PV and battery circuits. In this standard, the term isolated inverter is used as defined above in general – referring to isolation between the mains and PV circuits. If two circuits other than the mains and PV circuits are being discussed, additional wording is used to clarify the meaning.

NOTE 2 For an inverter that does not have internal isolation between the mains and PV circuits, but is required to be used with a dedicated isolation transformer, with no other equipment connected to the inverter side of that isolation transformer, the combination may be treated as an isolated inverter. Other configurations require analysis at the system level, and are beyond the scope of this standard, however the principles in this standard may be used in the analysis.

3.107
multiple mode inverter
an inverter that operates in more than one mode, for example having grid-interactive functionality when mains voltage is present, and stand-alone functionality when the mains is de-energized or disconnected

3.108
non-isolated inverter
an inverter without at least simple separation between the mains and PV circuits

NOTE See the notes under 3.106 above.

3.109
stand-alone inverter
an inverter or inverter function intended to supply AC power to a load that is not connected to the mains.

NOTE Stand-alone inverters may be designed to be paralleled with other non-mains sources (other inverters, rotating generators, etc.). Such a system does not constitute a grid-interactive system.

4 General testing requirements

This clause of Part 1 is applicable except as follows:

NOTE In IEC 62109-1 and therefore in this Part 2, test requirements that relate only to a single type of hazard (shock, fire, etc.) are located in the clause specific to that hazard type. Test requirements that relate to more than one type of hazard (for example testing under fault conditions) or that provide general test conditions, are located in this Clause 4.

4.4 Testing in single fault condition

4.4.4 Single fault conditions to be applied

Additional subclauses:

4.4.4.15 Fault-tolerance of protection for grid-interactive inverters

4.4.4.15.1 Fault-tolerance of residual current monitoring

Where protection against hazardous residual currents according to 4.8.3.5 is required, the residual current monitoring system must be able to operate properly with a single fault applied, or must detect the fault or loss of operability and cause the inverter to indicate a fault in accordance with 13.9, and disconnect from, or not connect to, the mains, no later than the next attempted re-start.

NOTE For a PV inverter, the “next attempted re-start” will occur no later than the morning following the fault occurring. Operation during that period of less than one day is allowed because it is considered highly unlikely that a fault in the monitoring system would happen on the same day as a person coming into contact with normally enclosed hazardous live parts of the PV system, or on the same day as a fire-hazardous ground fault.

Compliance is checked by testing with the grid-interactive inverter connected as in reference test conditions in Part 1. Single faults are to be applied in the inverter one at a time, for example in the residual current monitoring circuit, other control circuits, or in the power supply to such circuits.

For each fault condition, the inverter complies if one of the following occurs:

a) the inverter ceases to operate, indicates a fault in accordance with 13.9, disconnects from the mains, and does not re-connect after any sequence of removing and reconnecting PV power, AC power, or both,

or

b) the inverter continues to operate, passes testing in accordance with 4.8.3.5 showing that the residual current monitoring system functions properly under the single fault condition, and indicates a fault in accordance with 13.9,

or

c) the inverter continues to operate, regardless of loss of residual current monitoring functionality, but does not re-connect after any sequence of removing and reconnecting PV power, AC power, or both, and indicates a fault in accordance with 13.9.

4.4.4.15.2 Fault-tolerance of automatic disconnecting means

4.4.4.15.2.1 General

The means provided for automatic disconnection of a grid-interactive inverter from the mains shall:

– disconnect all grounded and ungrounded current-carrying conductors from the mains, and

– be such that with a single fault applied to the disconnection means or to any other location in the inverter, at least basic insulation or simple separation is maintained between the PV array and the mains when the disconnecting means is intended to be in the open state.

4.4.4.15.2.2 Design of insulation or separation

The design of the basic insulation or simple separation referred to in 4.4.4.15.2.1 shall comply with the following:

– the basic insulation or simple separation shall be based on the PV circuit working voltage, impulse withstand voltage, and temporary over-voltage, in accordance with 7.3.7 of Part 1;

– the mains shall be assumed to be disconnected;

– the provisions of 7.3.7.1.2 g) of Part 1 may be applied if the design incorporates means to reduce impulse voltages, and where required by 7.3.7.1.2 of Part 1, monitoring of such means;

– in determining the clearance based on working voltage in 7.3.7 of Part 1, the values of column 3 of Table 13 of Part 1 shall be used.

NOTE 1 These requirements are intended to protect workers who are servicing the AC mains system. In that scenario the mains will be disconnected, and the hazard being protected against is the array voltage appearing on the disconnected mains wiring, either phase-to-phase, or phase-to-earth. Therefore it is the PV array parameters (working voltage, impulse withstand voltage, and temporary over-voltage) that determine the required insulation or separation. The worker may be in a different location than any PV disconnection means located between the array and the inverter, or may not have access, so the insulation or separation provided in the inverter must be relied on. In a non-isolated inverter, only the required automatic disconnection means separates the mains service worker from the PV voltage. In an isolated inverter, the isolation transformer and other isolation components are in series with the automatic disconnection means, and separate the worker from the PV voltage in the event of failure of the automatic disconnection means.

NOTE 2 Example for a single-phase non-isolated inverter: Assume a non-isolated inverter rated for a floating array with a PV maximum input rating of 1 000 V d.c., and intended for use on a single-phase AC mains with an earthed neutral. See Figure 20 below.

– Subclause 4.4.4.15.2.1 requires the design to provide basic insulation after application of a single fault, in order to protect against shock hazard from the PV voltage for someone working on the mains circuits.

– One common method for achieving the required fault tolerant automatic disconnection means is to use 2 relays (a1 and b1 in Figure 20 below) in the ungrounded AC conductor (line), and another 2 relays (a2 and b2) in the grounded conductor (neutral). The required single-fault tolerance can then be arranged by having 2 separate relay control circuits (Control A and B) each controlling one line relay and one neutral relay. In any single fault scenario involving one control circuit or one relay, there will still be at least one relay in the line and one relay in the neutral that can properly open to isolate both mains circuit conductors from the inverter and therefore from the array.

– Since the mains neutral is earthed in this example, there is single fault protection from a possible shock hazard between the neutral and earth regardless of isolation of the mains from the inverter and the PV array. Therefore the shock hazard the relays need to protect against is from the mains line conductor to earth or neutral.
– The single fault scenario prevents one pair of relays from opening, but leaves the remaining un-faulted pair of relays properly able to open and to provide the required basic insulation.
– In order for a shock to occur, current would have to flow from the mains line conductor, through the person, to earth or neutral, and back to the line conductor through both of the remaining relay gaps in series. Therefore the required basic insulation is provided by the total of the air gaps in the two remaining relays.
– From Table 12 of Part 1, the impulse voltage withstand rating for a PV circuit system voltage of 1000 V dc is 4 464 V. From Table 13 of Part 1, the required total clearance is 3,58 mm divided between the air gaps in the two remaining relays. If identical relays are used, each relay must provide approximately 1,8 mm clearance. The required creepage across the open relays depends on the pollution degree and material group, is based on 1000 V d.c., and is divided between the air gaps in the two remaining relays.
– Similar analysis can be done for other system and inverter topologies.

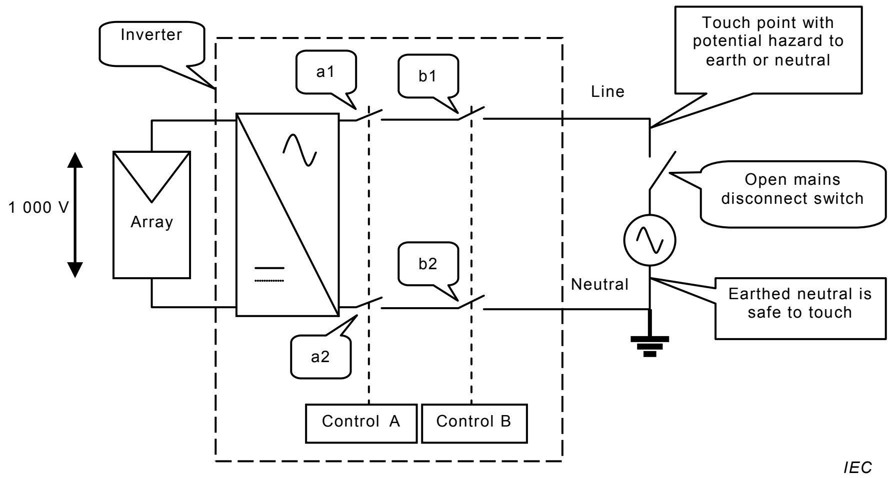


Figure 20 – Example system discussed in Note 2 above

4.4.4.15.2.3 Automatic checking of the disconnect means

For a non-isolated inverter, the isolation provided by the automatic disconnection means shall be automatically checked before the inverter starts operation. After the isolation check, if the check fails, any still-functional disconnection means shall be left in the open position, at least basic insulation or simple separation shall be maintained between the PV input and the mains, the inverter shall not start operation, and the inverter shall indicate a fault in accordance with 13.9.

Compliance with 4.4.4.15.2.1 through 4.4.4.15.2.3 is checked by inspection of the PCE and schematics, evaluation of the insulation or separation provided by components, and for non-isolated inverters by the following test:

With the non-isolated grid-interactive inverter connected and operating as in reference test conditions in Part 1, single faults are to be applied to the automatic disconnection means or to other relevant parts of the inverter. The faults shall be chosen to render all or part of the disconnection means inoperable, for example by defeating control means or by short-circuiting one switch pole at a time. With the inverter operating, the fault is applied, and then PV input voltage is removed or lowered below the minimum required for inverter operation, to trigger a disconnection from the mains. The PV input voltage is then raised back up into the operational range. After the inverter completes its isolation check, any still-functional disconnection means shall be in the open position, at least basic insulation or simple separation shall be maintained between the PV input and the mains, the inverter shall not start operation, and the inverter shall indicate a fault in accordance with 13.9.

In all cases, the non-isolated grid-interactive inverter shall comply with the requirements for basic insulation or simple separation between the mains and the PV input following application of the fault.

4.4.4.16 Stand-alone inverters – Load transfer test

A stand-alone inverter with a transfer switch to transfer AC loads from the mains or other AC bypass source to the inverter output shall continue to operate normally and shall not present a risk of fire or shock as the result of an out-of-phase transfer.

Compliance is checked by the following test. The bypass a.c. source is to be displaced 180° from the a.c. output of a single-phase inverter and 120° for a 3-phase supply. The transfer switch is to be subjected to one operation of switching the load from the a.c. output of the inverter to the bypass a.c. source. The load is to be adjusted to draw maximum rated a.c. power.

For an inverter employing a bypass switch having a control preventing switching between two a.c. sources out of synchronization, the test is to be conducted under the condition of a component malfunction when such a condition could result in an out-of-phase transfer between the two a.c. sources of supply.

4.4.4.17 Cooling system failure – Blanketing test

In addition to the applicable tests of subclause 4.4.4.8 of Part 1, inadvertent obstruction of the airflow over an exposed external heatsink shall be one of the fault conditions considered. No hazards according to the criteria of subclause 4.4.3 of Part 1 shall result from blanketing the inverter in accordance with the test below.

This test is not required for inverters restricted to use only in closed electrical operating areas.

NOTE The intent of this testing is to simulate unintentional blanketing that may occur after installation, due to lack of user awareness of the need for proper ventilation. For example, inverters for residential systems may be installed in spaces such as closets that originally allow proper ventilation, but later get used for storage of household goods. In such a situation, the heatsink may have materials resting against it that block convection and prevent heat exchange with the ambient air. Tests for blocked ventilation openings and failed fans are contained in Part 1, but not for blanketing of a heatsink.

Compliance is checked by the following test, performed in accordance with the requirements of subclause 4.4.2 of Part 1 along with the following.

The inverter shall be mounted in accordance with the manufacturer's installation instructions. If more than one position or orientation is allowed, the test shall be performed in the orientation or position that is most likely to result in obstruction of the heatsink after installation. The entire inverter including any external heatsink provided shall be covered in surgical cotton with an uncompressed thickness of minimum 2 cm, covering all heatsink fins and air channels. This surgical cotton replaces the cheesecloth required by subclause 4.4.3.2 of Part 1. The inverter shall be operated at full power. The duration of the test shall be a minimum of 7 h except that the test may be stopped when temperatures stabilize if no external surface of the inverter is at a temperature exceeding 90 °C.

4.7 Electrical ratings tests

Additional subclauses:

4.7.3 Measurement requirements for AC output ports for stand-alone inverters

Measurements of the AC output voltage and current on a stand-alone inverter shall be made with a meter that indicates the true RMS value.

NOTE Some non-sinusoidal inverter output waveforms will not be properly measured if an average responding meter is used.

4.7.4 Stand-alone Inverter AC output voltage and frequency

4.7.4.1 General

The AC output voltage and frequency of a stand-alone inverter, or multi-mode inverter operating in stand-alone mode, shall comply with the requirements of 4.7.4.2 to 4.7.4.5.

4.7.4.2 Steady state output voltage at nominal DC input

The steady-state AC output voltage shall not be less than 90 % or more than 110 % of the rated nominal voltage with the inverter supplied with its nominal value of DC input voltage.

Compliance is checked by measuring the AC output voltage with the inverter supplying no load, and again with the inverter supplying a resistive load equal to the inverters rated maximum continuous output power in stand-alone mode. The AC output voltage is measured after any transient effects from the application or removal of the load have ceased.

4.7.4.3 Steady state output voltage across the DC input range

The steady-state AC output voltage shall not be less than 85 % or more than 110 % of the rated nominal voltage with the inverter supplied with any value within the rated range of DC input voltage.

Compliance is checked by measuring the AC output voltage under four sets of conditions: with the inverter supplying no load and supplying a resistive load equal to the inverters rated maximum continuous output power in stand-alone mode, both at the minimum rated DC input voltage and at the maximum rated DC input voltage. The AC output voltage is measured after any transient effects from the application or removal of the load have ceased.

4.7.4.4 Load step response of the output voltage at nominal DC input

The AC output voltage shall not be less than 85 % or more than 110 % of the rated nominal voltage for more than 1,5 s after application or removal of a resistive load equal to the inverter's rated maximum continuous output power in stand-alone mode, with the inverter supplied with its nominal value of DC input voltage.

Compliance is checked by measuring the AC output voltage after a resistive load step from no load to full rated maximum continuous output power, and from full power to no load. The RMS output voltage of the first complete cycle coming after t = 1,5 s is to be measured, where t is the time measured from the application of the load step change.

4.7.4.5 Steady state output frequency

The steady-state AC output frequency shall not vary from the nominal value by more than +4 % or –6 %.

Compliance is checked by measuring the AC output frequency under four sets of conditions: with the inverter supplying no load and supplying a resistive load equal to the inverters rated maximum continuous output power in stand-alone mode, at both the minimum rated DC input voltage and at the maximum rated DC input voltage. The AC output frequency is measured after any transient effects from the application or removal of the load have ceased.

4.7.5 Stand-alone inverter output voltage waveform

4.7.5.1 General

The AC output voltage waveform of a stand-alone inverter, or multi-mode inverter operating in stand-alone mode, shall comply with the requirements in 4.7.5.2 for sinusoidal outputs, or 4.7.5.3 and 4.7.5.4 for intentionally non-sinusoidal outputs, or with the dedicated load requirements in 4.7.5.5.

4.7.5.2 Sinusoidal output voltage waveform requirements

The AC output waveform of a sinusoidal output stand-alone inverter shall have a total harmonic distortion (THD) not exceeding of 10 % and no individual harmonic at a level exceeding 6 %.

Compliance is checked by measuring the THD and the individual harmonic voltages with the inverter delivering 5 % power or the lowest continuous available output power greater than 5 %, and 50 % and 100 % of its continuous rated output power, into a resistive load, with the inverter supplied with nominal DC input voltage. The limits above are relative to the magnitude of the fundamental component at each of the load levels above. The THD measuring instrument shall measure the sum of the harmonics from n=2 to n=40 as a percentage of the fundamental (n=1) component.

4.7.5.3 Non-sinusoidal output waveform requirements

4.7.5.3.1 General

The AC output voltage waveform of a non-sinusoidal output stand-alone inverter shall comply with the requirements of 4.7.5.3.2 to 4.7.5.3.4.

4.7.5.3.2 Total harmonic distortion

The total harmonic distortion (THD) of the voltage waveform shall not exceed 40 %.

4.7.5.3.3 Waveform slope

The slope of the rising and falling edges of the positive and negative half-cycles of the voltage waveform shall not exceed 10 V/μs measured between the points at which the waveform has a voltage of 10 % and 90 % of the peak voltage for that half-cycle.

4.7.5.3.4 Peak voltage

The absolute value of the peak voltage of the positive and negative half-cycles of the waveform shall not exceed 1,414 times 110 % of the RMS value of the rated nominal AC output voltage.

Compliance with 4.7.5.3.2 through 4.7.5.3.4 is checked by measuring the THD, slopes, and peak voltages of the output voltage waveform with the inverter delivering 5 % power or the lowest continuous available output power greater than 5 %, and 50 % and 100 % of its continuous rated output power, into a resistive load. Each test shall be performed at the DC input voltage, within the rated range for the inverter, that creates the worst-case condition for that test. The THD measuring instrument shall measure the sum of the harmonics from n=2 to n=40 as a percentage of the fundamental (n=1) component.

4.7.5.4 Information requirements for non-sinusoidal waveforms

The instructions provided with a stand-alone inverter not complying with 4.7.5.2 shall include the information in 5.3.2.6.

4.7.5.5 Output voltage waveform requirements for inverters for dedicated loads

For an inverter that is intended only for use with a known dedicated load, the following requirements may be used as an alternative to the waveform requirements in 4.7.5.2 to 4.7.5.3.

The combination of the inverter and dedicated load shall be evaluated to ensure that the output waveform does not cause any hazards in the load equipment and inverter, or cause the load equipment to fail to comply with the applicable product safety standards.

Compliance is checked through testing and analysis. Tests as required by this standard and the standard applicable to the dedicated load equipment, shall be performed to determine if the inverter output waveform causes a failure to comply with the applicable requirements. A particular test may be omitted if analysis shows that the output waveform would not have any possible effect on safety relevant parameters.

NOTE The possible effects of the output waveform include, but are not limited to, aspects such as heating, clearances relative to the peak voltage of the inverter waveform, increased input current, breakdown of solid insulation or components due to excessive peak voltages or rise times, misoperation of control circuits, particularly protective circuitry, etc.

The inverter shall be marked with symbols 9 and 15 of Table C.1 of Part 1.

The installation instructions provided with the inverter shall include the information in 5.3.2.13.

Additional subclause:

4.8 Additional tests for grid-interactive inverters

4.8.1 General requirements regarding inverter isolation and array grounding

Inverters may or may not provide galvanic isolation from the mains to the PV array, and the array may or may not have one side of the circuit grounded. Inverters shall comply with the requirements in Table 30 for the applicable combination of inverter isolation and array grounding.

Table 30 – Requirements based on inverter isolation and array grounding [1)]

<table>
<tr><th>Array grounding:</th><th>Ungrounded[a] or functionally grounded</th><th>Ungrounded or functionally grounded</th><th>Grounded</th></tr>
<tr><th>Inverter isolation:</th><th>Non-isolated</th><th>Isolated</th><th>Isolated</th></tr>
<tr><td>Minimum inverter isolation requirements</td><td>Not applicable</td><td colspan="2">Basic or reinforced [b] insulation
and
Leakage current type testing per 4.8.3.2 (shock hazard) and 4.8.3.3 (fire hazard) to determine the requirements for array ground insulation resistance and array residual current detection, below</td></tr>
<tr><td>Array ground insulation resistance measurement</td><td>Before starting operation, per 4.8.2.1 or 4.8.2.2
Action on fault: indicate a fault in accordance with 13.9, and do not connect to the mains</td><td>Before starting operation, per 4.8.2.1 or 4.8.2.2
Action on fault:
For inverters with isolation complying with the leakage current limits for both shock and fire hazards under “Minimum inverter isolation requirements” above, indicate a fault in accordance with 13.9
For inverters with isolation not complying with the above minimum leakage current values, indicate a fault in accordance with 13.9, and do not connect to the mains</td><td>Not required [d]</td></tr>
<tr><td>Array residual current detection</td><td>Either
a) 30 mA RCD[c] between the inverter and the mains per 4.8.3.4, or
b) monitoring for both continuous excessive residual current per 4.8.3.5.1 a) and excessive sudden changes per 4.8.3.5.1 b)
Action on fault: shut down the inverter, disconnect from the mains, and indicate a fault in accordance with 13.9</td><td colspan="2">Not applicable for inverters with isolation complying with the leakage current limits for both shock and fire hazards under “Minimum inverter isolation requirements” above.
Inverters with isolation not complying with the leakage current limits for shock hazard per 4.8.3.2 require monitoring for sudden changes in residual current per 4.8.3.5.1 b) or use of an RCD per 4.8.3.4
Inverters with isolation not complying with the leakage current limits for fire hazard per 4.8.3.3 require monitoring for excessive continuous residual current per 4.8.3.5.1 a) or use of an RCD per 4.8.3.4
Action on fault: shut down the inverter, disconnect from the mains, and indicate a fault in accordance with 13.9.</td></tr>
</table>

NOTE Some non-isolated inverter topologies with a grounded array are technologically possible, but IEC 60364-7-712 requires simple separation between the mains and the PV if the array is grounded. A non-isolated inverter where the only connection of the array to ground is through the mains neutral connection to earth is allowed under IEC 60364-7-712 because the system design does not allow current to flow on grounding conductors under normal conditions (except for expected leakage current), and the functionality of any RCD in the system is not impaired.

[a] If the only connection of the array to ground is on the mains side of the inverter automatic disconnection means (through the neutral connection to earth), then the array is considered ungrounded.

[b] An inverter for use with an array of decisive voltage classification DVC-A is required to use at least reinforced insulation (protective separation) between the array and DVC-B and -C circuits such as the mains.

[c] For some types of inverters a type B RCD is required. See 4.8.3.4.

[d] New information at the time of publication indicates that grounded arrays would benefit from the additional protection offered by the use of array ground insulation resistance measurement before inverter connection to the grid. That added protection feature can significantly reduce the risk of fire hazards on grounded arrays due to ground faults caused by improper system installation, commissioning, or maintenance, leading to undetected first ground faults followed by subsequent additional ground faults. Table 30 above indicates "Not required" for this technique on

1) As noted in the Foreword, the numbering of tables and figures in this Part 2 continues the existing numbering scheme in Part 1 to avoid any confusion that might arise from identical numbering between the two parts.

inverters for grounded arrays, but an IEC 62109-2 amendment is planned for the near future and requirements are under consideration for improved ground fault protection for grounded arrays. At that time IEC 62109-2 will also be coordinated with the system protection requirements in IEC 62548 currently under development.

4.8.2 Array insulation resistance detection for inverters for ungrounded and functionally grounded arrays

NOTE The requirements in this subclause regarding detection and response to abnormal array insulation resistance to ground are intended to reduce fire or shock hazard due to an inadvertent connection between the array and ground. In a non-isolated inverter, an array ground fault will result in potentially hazardous current flow as soon as the inverter connects to the mains, due to the earthed neutral on the mains, so the inverter must not connect to the mains. In an isolated inverter, if a first ground fault in a floating or functionally grounded array goes undetected, a second ground fault can cause hazardous current to flow. The detection and indication of the first fault is required, but the inverter is allowed to connect and commence operating, because the isolation in the inverter means the earthed neutral on the mains will not provide a return current path for the fault current.

4.8.2.1 Array insulation resistance detection for inverters for ungrounded arrays

Inverters for use with ungrounded arrays shall have means to measure the DC insulation resistance from the PV input (array) to ground before starting operation, or shall be provided with installation instructions in accordance with 5.3.2.11.

If the insulation resistance is less than $R = (V_{\text{MAX PV}}/30\ \text{mA})$ ohms, the inverter:

– for isolated inverters, shall indicate a fault in accordance with 13.9 (operation is allowed); the fault indication shall be maintained until the array insulation resistance has recovered to a value higher than the limit above;

– for non-isolated inverters, or inverters with isolation not complying with the leakage current limits in the minimum inverter isolation requirements in Table 30, shall indicate a fault in accordance with 13.9, and shall not connect to the mains; the inverter may continue to make the measurement, may stop indicating a fault and may connect to the mains if the array insulation resistance has recovered to a value higher than the limit above.

The measurement circuit shall be capable of detecting insulation resistance below the limit above, under normal conditions and with a ground fault in the PV array.

Compliance is checked by analysis of the design and by testing, as follows:

Compliance with the values of current shall be determined using an RMS meter that responds to both the AC and DC components of the current, with a bandwidth of at least 2 kHz.

The inverter shall be connected to PV and AC sources as specified in the reference test conditions in Part 1, except with the PV voltage set below the minimum operating voltage required for the inverter to attempt to start operating. A resistance 10 % less than the limit above shall be connected between ground and each PV input terminal of the inverter, in turn, and then the PV input voltage shall be raised to a value high enough that the inverter attempts to begin operation. The inverter shall indicate a fault in accordance with 13.9 and take the action (operating or not operating as applicable) required above.

It is not required to test all PV input terminals if analysis of the design indicates that one or more terminals can be expected to have the same result, for example where multiple PV string inputs are in parallel.

NOTE The resistance to ground of the DC supply or simulated array used to power the inverter during this test, must be taken into account unless it is large enough not to significantly influence the test result.

4.8.2.2 Array insulation resistance detection for inverters for functionally grounded arrays

Inverters that functionally ground the array through an intentional resistance integral to the inverter, shall meet the requirements in a) and c), or b) and c) below:

NOTE System designers using resistance between the array and ground that is not integral to the inverter, must consider whether a shock hazard on the array is created or made worse by the addition of the resistance, based on the array design, resistance value, protection against direct contact with the array, etc. Requirements for such considerations are not included here because if the inverter does not provide the resistance, it is neither the cause of, nor capable of protecting against, the hazard.

a) The value of the total resistance, including the intentional resistance for array functional grounding, the expected insulation resistance of the array to ground, and the resistance of any other networks connected to ground (for example measurement networks) must not be lower than $R = (V_{MAX\ PV}/30\ mA)$ ohms. The expected insulation resistance of the array to ground shall be calculated based on an array insulation resistance of 40 MΩ per m^2, with the surface area of the panels either known, or calculated based on the inverter power rating and the efficiency of the worst-case panels that the inverter is designed to be used with.

NOTE Designers should consider adding design margin, based on considerations such as panel aging which will reduce the array insulation resistance over time and any AC component of the leakage current caused by array capacitance to ground. The array insulation resistance measurement in c) below will ensure that total resistance is not too low and the system remains safe, but if the design margin is not adequate, the system will refuse to connect following the array insulation resistance check.

The installation instructions shall include the information required in 5.3.2.12.

b) As an alternative to a), or if a resistor value lower than in a) is used, the inverter shall incorporate means to detect, during operation, if the total current through the resistor and any networks (for example measurement networks) in parallel with it, exceeds the residual current values and times in Table 31 and shall either disconnect the resistor or limit the current by other means. If the inverter is a non-isolated inverter, or has isolation not complying with the leakage current limits in the minimum inverter isolation requirements in Table 30, it shall also disconnect from the mains.

The inverter may attempt to resume normal operation if the array insulation resistance has recovered to a value higher than the limit in 4.8.2.1.

NOTE For the inverter to make the measurement of array insulation resistance and meet the limit in 4.8.2.1, the array functional grounding resistor will need to remain disconnected (or the current limiting means will have to remain in effect) until after the array insulation resistance measurement has been made.

Compliance with a) or b) is checked by analysis of the design and for case b) above, by the test for detection of sudden changes in residual current in 4.8.3.5.3.

c) The inverter shall have means to measure the DC insulation resistance from the PV input to ground before starting operation, in accordance with 4.8.2.1.

4.8.3 Array residual current detection

4.8.3.1 General

Ungrounded arrays operating at DVC-B and DVC-C voltages can create a shock hazard if live parts are contacted and a return path for touch current exists. In a non-isolated inverter, or an inverter with isolation that does not adequately limit the available touch current, the connection of the mains to earth (i.e. the earthed neutral) provides a return path for touch current if personnel inadvertently contact live parts of the array and earth at the same time. The requirements in this section provide additional protection against this shock hazard through the application of residual current detectors (RCD's) per 4.8.3.4 or by monitoring for sudden changes in residual current per 4.8.3.5, except neither is required in an isolated inverter where the isolation provided limits the available touch current to less than 30 mA when tested in accordance with 4.8.3.2.

Ungrounded and grounded arrays can create a fire hazard if a ground fault occurs that allows excessive current to flow on conductive parts or structures that are not intended to carry current. The requirements in this section provide additional protection against this fire hazard by application of RCD's per 4.8.3.4 or by monitoring for continuous excessive residual current per 4.8.3.5, except neither is required in an isolated inverter where the isolation provided limits the available current to less than:

– 300 mA RMS for inverters with rated continuous output power ≤ 30 kVA, or
– 10 mA RMS per kVA of rated continuous output power for inverters with rated continuous output power rating > 30 kVA.

when tested in accordance with 4.8.3.3.

NOTE In the above paragraphs and in the following tests, the current is defined in different ways. The 30 mA limit on touch currents is tested using a human body model touch current test circuit, since that requirement relates to shock hazard. The current limit for fire hazard purposes is measured using a standard ammeter and no human body model circuit because the fire hazard is related to current in an unintended conductor, not current in the human body.

4.8.3.2 30 mA touch current type test for isolated inverters

Compliance with the 30 mA limit in 4.8.3.1 is tested with the inverter connected and operating under reference test conditions, except that the DC supply to the inverter must not have any connection to earth, and the mains supply to the inverter must have one pole earthed. It is acceptable (and may be necessary) to defeat array insulation resistance detection functions during this test. The touch current measurement circuit of IEC 60990, Figure 4 is connected from each terminal of the array to ground, one at a time. The resulting touch current is recorded and compared to the 30 mA limit, to determine the requirements for array ground insulation resistance and array residual current detection in Table 30.

NOTE 1 For convenience, IEC 60990 test figure 4 is reproduced in Annex H of Part 1.

NOTE 2 Consideration should be given to the impact on the touch current measurement that capacitance between external test sources and earth could have on the result (for example a d.c. supply with capacitors to earth can increase the measured touch current unless the d.c. supply is not earthed to the same earth as the PCE under test).

4.8.3.3 Fire hazard residual current type test for isolated inverters

Compliance with the 300 mA or 10 mA per kVA limit in 4.8.3.1 is tested with the inverter connected and operating under reference test conditions, except that the DC supply to the inverter must not have any connection to earth, and the mains supply to the inverter must have one pole earthed. It is acceptable (and may be necessary) to defeat array insulation resistance detection functions during this test. An ammeter is connected from each PV input terminal of the inverter to ground, one at a time. The ammeter used shall be an RMS meter that responds to both the AC and DC components of the current, with a bandwidth of at least 2 kHz.

The current is recorded and compared to the limit in 4.8.3.1, to determine the requirements for array ground insulation resistance and array residual current detection in Table 30.

NOTE Consideration should be given to the impact on the current measurement that capacitance between external test sources and earth could have on the result (for example a d.c. supply with capacitors to earth can increase the measured current unless the d.c. supply is not earthed to the same earth as the PCE under test).

4.8.3.4 Protection by application of RCD's

The requirement for additional protection in 4.8.3.1 can be met by provision of an RCD with a residual current setting of 30 mA, located between the inverter and the mains. The selection of the RCD type to ensure compatibility with the inverter must be made according to rules for RCD selection in Part 1. The RCD may be provided integral to the inverter, or may be provided by the installer if details of the rating, type, and location for the RCD are given in the installation instructions per 5.3.2.9.

4.8.3.5 Protection by residual current monitoring

4.8.3.5.1 General

Where required by Table 30, the inverter shall provide residual current monitoring that functions whenever the inverter is connected to the mains with the automatic disconnection means closed. The residual current monitoring means shall measure the total (both a.c. and d.c. components) RMS current.

As indicated in Table 30 for different inverter types, array types, and inverter isolation levels, detection may be required for excessive continuous residual current, excessive sudden changes in residual current, or both, according to the following limits:

a) Continuous residual current: The inverter shall disconnect within 0,3 s and indicate a fault in accordance with 13.9 if the continuous residual current exceeds:
   - maximum 300 mA for inverters with continuous output power rating ≤ 30 kVA;
   - maximum 10 mA per kVA of rated continuous output power for inverters with continuous output power rating > 30 kVA.

The inverter may attempt to re-connect if the array insulation resistance meets the limit in 4.8.2.

b) Sudden changes in residual current: The inverter shall disconnect from the mains within the time specified in Table 31 and indicate a fault in accordance with 13.9, if a sudden increase in the RMS residual current is detected exceeding the value in the table.

Table 31 – Response time limits for sudden changes in residual current

Residual current sudden change	Max time to inverter disconnection from the mains
30 mA	0,3 s
60 mA	0,15 s
150 mA	0,04 s

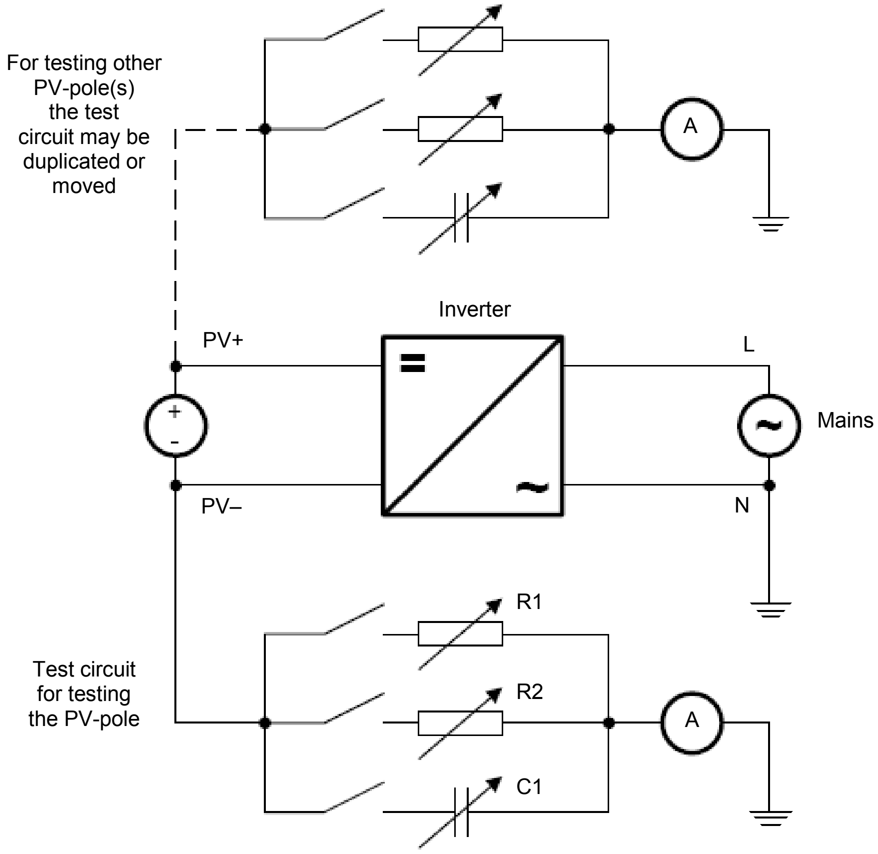
NOTE These values of residual current and time are based on the RCD standard IEC 61008-1.

Exceptions:

- monitoring for the continuous condition in a) is not required for an inverter with isolation complying with 4.8.3.3;
- monitoring for the sudden changes in b) is not required for an inverter with isolation complying with 4.8.3.2.

The inverter may attempt to re-connect if the array insulation resistance meets the limit in 4.8.2.

Compliance with a) and b) is checked by the tests of 4.8.3.5.2 and 4.8.3.5.3 respectively. Compliance with the values of current shall be determined using an RMS meter that responds to both the AC and DC components of the current, with a bandwidth of at least 2 kHz. An example of a test circuit is given in Figure 21 below.



For the continuous residual current test, R1 establishes a baseline current just below the trip point, and R2 is switched in to cause the current to exceed the trip point. Capacitor C1 is not used.

For the sudden change residual current test, C1 establishes a baseline current and R1 or R2 is switched in to cause the desired value of sudden change. The other resistor is not used.

IEC 1013/11

Figure 21 – Example test circuit for residual current detection testing

4.8.3.5.2 Test for detection of excessive continuous residual current

An external adjustable resistance is connected from ground to one PV input terminal of the inverter. The resistance shall be steadily lowered in an attempt to exceed the residual current limit in a) above, until the inverter disconnects. This determines the actual trip level of the sample under test, which shall be less than or equal to the continuous residual current limit above. To test the trip time, the test resistance is then adjusted to set the residual current to a value approximately 10 mA below the actual trip level. A second external resistance, adjusted to cause approximately 20 mA of residual current to flow, is connected through a switch from ground to the same PV input terminal as the first resistance. The switch is closed, increasing the residual current to a level above the trip level determined above. The time shall be measured from the moment the second resistance is connected until the moment the inverter disconnects from the mains, as determined by observing the inverter output current and measuring the time until the current drops to zero.

This test shall be repeated 5 times, and for all 5 tests the time to disconnect shall not exceed 0,3 s.

The test is repeated for each PV input terminal. It is not required to test all PV input terminals if analysis of the design indicates that one or more terminals can be expected to have the same result, for example where multiple PV string inputs are in parallel.

NOTE The approximate values of 10 mA and 20 mA above are not critical, but it is important to ensure that the residual current change applied is small enough to trigger disconnection due to the continuous residual current detection system, not due to the sudden change residual current detection system

4.8.3.5.3 Test for detection of sudden changes in residual current

This test shows that the residual current sudden change function operates within the limits for residual current and trip time, even when the sudden change is superimposed over a pre-existing baseline level of continuous residual current.

a) Setting the pre-existing baseline level of continuous residual current: An adjustable capacitance is connected to one PV terminal. This capacitance is slowly increased until the inverter disconnects by means of the continuous residual current detection function. The capacitance is then lowered such that the continuous residual current is reduced below that disconnection level, by an amount equal to approximately 150 % of the first residual current sudden change value in 4.8.3.5.1 b) to be tested (e.g. 45 mA for the 30 mA test) and the inverter is re-started.
b) Applying the sudden change in residual current: An external resistance, pre-adjusted to cause 30 mA of residual current to flow, is connected through a switch from ground to the same PV input terminal as the capacitance in step a) above. The time shall be measured from the moment the switch is closed (i.e. connecting the resistance and applying the residual current sudden change) until the moment the inverter disconnects from the grid, as determined by observing the inverter output current and measuring the time until the current drops to zero. This test shall be repeated 5 times, and all 5 results shall not exceed the time limit indicated in the 30 mA row of Table 31.

Steps a) and b) shall then be repeated for the 60 mA and 150 mA values and times in Table 31.

The above set of tests shall then be repeated for each PV terminal. It is not required to test all PV input terminals if analysis of the design indicates that one or more terminals can be expected to have the same result, for example where multiple PV string inputs are in parallel.

If the inverter topology is such that the AC component of the voltage on the PV terminals is very small, a very large amount of capacitance may be needed to perform step a) of this test. In this case it is allowable to use resistance in place of or in addition to the capacitance to achieve the required amount of residual current. This method may not be used on inverter topologies that result in an AC component on the PV terminals that is equal to or greater than the RMS value of the half-wave rectified mains voltage.

For inverters with high power ratings, because the limit increases with power rating, a very large amount of capacitance may be needed to perform step a) of this test. In cases where this is impractical, it is allowable to use resistance in place of or in addition to the capacitance to achieve the required amount of residual current. This method may only be used if analysis of the detection method and circuitry proves that the detection system can accurately measure resistive, capacitive, and mixed types of current.

4.8.3.6 Systems located in closed electrical operating areas

For systems in which the inverter and a DVC-B or DVC-C PV array are located in closed electrical operating areas, the protection against shock hazard on the PV array in subclauses 4.8.2.1, 4.8.2.2, 4.8.3.2, 4.8.3.4, and 4.8.3.5.1 b) is not required if the installation information provided with the inverter indicates the restriction for use in a closed electrical operating area, and indicates what forms of shock hazard protection are and are not provided integral to the inverter, in accordance with 5.3.2.7. The inverter shall be marked as in 5.2.2.6.

5 Marking and documentation

This clause of Part 1 is applicable with the following exceptions:

5.1 Marking

5.1.4 Equipment ratings

Replacement:

In addition to the markings required in other clauses of Part 1 and elsewhere in this Part 2, the ratings in Table 32 shall be plainly and permanently marked on the inverter, where it is readily visible after installation. Only those ratings that are applicable based on the type of inverter are required.

NOTE For example a.c. input quantities are only required for inverters having an a.c. input port in addition to the a.c. output port, or a single a.c. port that may operate as an input in one or more modes.

Table 32 – Inverter ratings – Marking requirements

Rating	Units
PV input ratings:	
Vmax PV[a] (absolute maximum)	d.c. V
Isc PV[a] (absolute maximum)	d.c. A
a.c. output ratings:	
Voltage (nominal or range)	a.c. V
Current (maximum continuous)	a.c. A
Frequency (nominal or range)	Hz
Power (maximum continuous)	W or VA
Power factor range	
a.c. input ratings:	
Voltage (nominal or range)	a.c. V
Current (maximum continuous)	a.c. A
Frequency (nominal or range)	Hz
d.c. input (other than PV) ratings:	
Voltage (nominal or range)	d.c. V
Current (maximum continuous)	d.c. A
d.c. output ratings:	
Voltage (nominal or range)	d.c. V
Current (maximum continuous)	d.c. A
Protective class[a] (I, II, or III)	
Ingress protection[a] (IP) rating per Part 1	
[a] These terms are defined in Clause 3 of Part 1.	

An inverter that is adjustable for more than one nominal output voltage shall be marked to indicate the particular voltage for which it is set when shipped from the factory. It is acceptable for this marking to be in the form of a removable tag or other non-permanent method.

5.2 Warning markings

5.2.2 Content for warning markings

Additional subclause:

5.2.2.6 Inverters for closed electrical operating areas

Where required by 4.8.3.6, an inverter not provided with full protection against shock hazard on the PV array shall be marked with a warning that the inverter is only for use in a closed electrical operating area, and referring to the installation instructions.

5.3 Documentation

5.3.2 Information related to installation

Additional subclauses:

5.3.2.1 Ratings

Subclause 5.3.2 of Part 1 requires the documentation to include ratings information for each input and output. For inverters this information shall be as in Table 33 below. Only those ratings that are applicable based on the type of inverter are required.

Table 33 – Inverter ratings – Documentation requirements

Rating	Units
PV input quantities:	
Vmax PV[a] (absolute maximum)	d.c. V
PV input operating voltage range	d.c. V
Maximum operating PV input current	d.c. A
Isc PV[a] (absolute maximum)	d.c. A
Max. inverter backfeed current to the array	a.c. or d.c. A
a.c. output quantities:	
Voltage (nominal or range)	a.c. V
Current (maximum continuous)	a.c. A
Current (inrush)	a.c. A (peak and duration)
Frequency (nominal or range)	Hz
Power (maximum continuous)	W or VA
Power factor range	
Maximum output fault current	a.c. A (peak and duration), or RMS[b]
Maximum output overcurrent protection	a.c. A
a.c. input quantities:	
Voltage (nominal or range)	a.c. V
Current (maximum continuous)	a.c. A
Current (inrush)	a.c. A (peak and duration)
Frequency (nominal or range)	Hz
d.c. input (other than PV) quantities:	
Voltage (nominal or range)	d.c. V
Nominal battery voltage	d.c. V
Current (maximum continuous)	d.c. A
d.c. output quantities:	
Voltage (nominal or range)	d.c. V
Nominal battery voltage	d.c. V
Current (maximum continuous)	d.c. A

Rating	Units
Protective class[a] (I, II, or III)	
Ingress protection[a] (IP) rating per Part 1	
[a] These terms are defined in section 3 of Part 1.	
[b] The output short circuit test section in Part 1 specifies the type of measurement and the required units for this rating.	

5.3.2.2 Grid-interactive inverter setpoints

For a grid-interactive unit with field adjustable trip points, trip times, or reconnect times, the presence of such controls, the means for adjustment, the factory default values, and the limits of the ranges of adjustability shall be provided in the documentation for the PCE or in other format such as on a website.

NOTE Some local interconnect standards require that adjustments to such setpoints must be protected by a password or made inaccessible to the user in some fashion. In the above requirement, the documentation for the "means for adjustment" is not meant to require the documentation to disclose the password or other security feature.

The settings of field adjustable setpoints shall be accessible from the PCE , for example on a display panel, user interface, or communications port.

5.3.2.3 Transformers and isolation

An inverter shall be provided with information to the installer regarding whether an internal isolation transformer is provided, and if so, what level of insulation (functional, basic, reinforced, or double) is provided by that transformer. The instructions shall also indicate what the resulting installation requirements are regarding such things as earthing or not earthing the array, providing external residual current detection devices, requiring an external isolation transformer, etc.

5.3.2.4 Transformers required but not provided

An inverter that requires an external isolation transformer not provided with the unit, shall be provided with instructions that specify the configuration type, electrical ratings, and environmental ratings for the external isolation transformer with which it is intended to be used.

5.3.2.5 PV modules for non-isolated inverters

Non-isolated inverters shall be provided with installation instructions that require PV modules that have an IEC 61730 Class A rating. If the maximum AC mains operating voltage is higher than the PV array maximum system voltage then the instructions shall require PV modules that have a maximum system voltage rating based upon the AC mains voltage.

5.3.2.6 Non-sinusoidal output waveform information

The instruction manual for a stand-alone inverter not complying with 4.7.5.2 shall include a warning that the waveform is not sinusoidal, that some loads may experience increased heating, and that the user should consult the manufacturers of the intended load equipment before operating that load with the inverter. The inverter manufacturer shall provide information regarding what types of loads may experience increased heating, recommendations for maximum operating times with such loads, and shall specify the THD, slope, and peak voltage of the waveforms as determined by the testing in 4.7.5.3.2 through 4.7.5.3.4.

5.3.2.7 Systems located in closed electrical operating areas

Where required by 4.8.3.6, an inverter not provided with full protection against shock hazard on the PV array shall be provided with installation instructions requiring that the inverter and the array must be installed in closed electrical operating areas, and indicating which forms of shock hazard protection are and are not provided integral to the inverter (for example the RCD, isolation transformer complying with the 30 mA touch current limit, or residual current monitoring for sudden changes).

5.3.2.8 Stand-alone inverter output circuit bonding

Where required by 7.3.10, the documentation for an inverter shall include the following:

– if output circuit bonding is required but is not provided integral to the inverter, the required means shall be described in the installation instructions, including which conductor is to be bonded and the required current carrying capability or cross-section of the bonding means;
– if the output circuit is intended to be floating, the documentation for the inverter shall indicate that the output is floating.

5.3.2.9 Protection by application of RCD's

Where the requirement for additional protection in 4.8.3.1 is met by requiring an RCD that is not provided integral to the inverter, as allowed by 4.8.3.4, the installation instructions shall state the need for the RCD, and shall specify its rating, type, and required circuit location.

5.3.2.10 Remote indication of faults

The installation instructions shall include an explanation of how to properly make connections to (where applicable), and use, the electrical or electronic fault indication required by 13.9.

5.3.2.11 External array insulation resistance measurement and response

The installation instructions for an inverter for use with ungrounded arrays that does not incorporate all the aspects of the insulation resistance measurement and response requirements in 4.8.2.1, must include:

– for isolated inverters, an explanation of what aspects of array insulation resistance measurement and response are not provided, and an instruction to consult local regulations to determine if any additional functions are required or not;
– for non-isolated inverters:
  - an explanation of what external equipment must be provided in the system, and
  - what the setpoints and response implemented by that equipment must be, and
  - how that equipment is to be interfaced with the rest of the system.

5.3.2.12 Array functional grounding information

Where approach a) of 4.8.2.2 is used, the installation instructions for the inverter shall include all of the following:

a) the value of the total resistance between the PV circuit and ground integral to the inverter;
b) the minimum array insulation resistance to ground that system designer or installer must meet when selecting the PV panel and system design, based on the minimum value that the design of the PV functional grounding in the inverter was based on;
c) the minimum value of the total resistance $R = V_{MAX\ PV}/30$ mA that the system must meet, with an explanation of how to calculate the total;
d) a warning that there is a risk of shock hazard if the total minimum resistance requirement is not met.

5.3.2.13 Stand-alone inverters for dedicated loads

Where the approach of 4.7.5.5 is used, the installation instructions for the inverter shall include a warning that the inverter is only to be used with the dedicated load for which it was evaluated, and shall specify the dedicated load.

5.3.2.14 Identification of firmware version(s)

An inverter utilizing firmware for any protective functions shall provide means to identify the firmware version. This can be a marking, but the information can also be provided by a display panel, communications port or any other type of user interface.

6 Environmental requirements and conditions

This clause of Part 1 is applicable.

7 Protection against electric shock and energy hazards

This clause of Part 1 is applicable with the following exceptions:

7.3 Protection against electric shock

Additional subclauses:

7.3.10 Additional requirements for stand-alone inverters

Depending on the supply earthing system that a stand-alone inverter is intended to be used with or to create, the output circuit may be required to have one circuit conductor bonded to earth to create a grounded conductor and an earthed system.

NOTE In single-phase and star-connected (wye-connected) three-phase systems this grounded conductor is also referred to as an earthed neutral.

The means used to bond the grounded conductor to protective earth may be provided within the inverter or as part of the installation. If not provided integral to the inverter, the required means shall be described in the installation instructions as per 5.3.2.8.

The means used to bond the grounded conductor to protective earth shall comply with the requirements for protective bonding in Part 1, except that if the bond can only ever carry fault currents in stand-alone mode, the maximum current for the bond is determined by the inverter maximum output fault current.

Output circuit bonding arrangements shall ensure that in any mode of operation, the system only has the grounded circuit conductor bonded to earth in one place at a time. Switching arrangements may be used, in which case the switching device used is to be subjected to the bond impedance test along with the rest of the bonding path.

Inverters intended to have a circuit conductor bonded to earth shall not impose any normal current on the bond except for leakage current.

Outputs that are intentionally floating with no circuit conductor bonded to ground, must not have any voltages with respect to ground that are a shock hazard in accordance with Clause 7 of Parts 1 and 2. The documentation for the inverter shall indicate that the output is floating as per 5.3.2.8.

7.3.11 Functionally grounded arrays

All PV conductors in a functionally grounded array shall be treated as being live parts with respect to protection against electric shock.

NOTE The intent of this requirement is to ensure that the functionally grounded conductor is not assumed to be at ground potential during evaluation of insulation coordination aspects such as clearance to ground etc., because its connection to ground does not comply with the requirements for protective bonding in Part 1.

8 Protection against mechanical hazards

This clause of Part 1 is applicable.

9 Protection against fire hazards

This clause of Part 1 is applicable with the following exceptions:

9.3 Short-circuit and overcurrent protection

Additional subclause:

9.3.4 Inverter backfeed current onto the array

The backfeed current testing and documentation requirements in Part 1 apply, including but not limited to the following.

Testing shall be performed to determine the current that can flow out of the inverter PV input terminals with a fault applied on inverter or on the PV input wiring. Faults to be considered include shorting all or part of the array, and any faults in the inverter that would allow energy from another source (for example the mains or a battery) to impress currents on the PV array wiring. The current measurement is not required to include any current transients that result from applying the short circuit, if such transients result from discharging storage elements other than batteries.

This inverter backfeed current value shall be provided in the installation instructions regardless of the value of the current, in accordance with Table 33.

NOTE This requirement protects against overloading of array wiring due to backfeed currents from the inverter. For example, such currents can be generated when fault conditions allow currents derived from other sources such as the mains or a battery to flow out of the PV input terminals of the inverter. If this backfeed current is limited to the maximum normal current the array can source, wiring and other devices in the current path will be adequately sized to carry the backfeed current without overload. If this backfeed current is not limited to the maximum normal current, providing the value of the max current to the installer is critical to allow determination of any increase in wiring sizes or added overcurrent protection necessary.

10 Protection against sonic pressure hazards

This clause of Part 1 is applicable.

11 Protection against liquid hazards

This clause of Part 1 is applicable.

12 Protection against chemical hazards

This clause of Part 1 is applicable.

13 Physical requirements

This clause of Part 1 is applicable with the following exception:

Additional subclause:

13.9 Fault indication

Where this Part 2 requires the inverter to indicate a fault, both of the following shall be provided:

a) a visible or audible indication, integral to the inverter, and detectable from outside the inverter, and

b) an electrical or electronic indication that can be remotely accessed and used.

The installation instructions shall include information regarding how to properly make connections (where applicable) and use the electrical or electronic means in b) above, in accordance with 5.3.2.10.

NOTE The requirement in b) is intended to allow a variety of techniques such as provision of a signal using relay contacts, an open-collector output, a message sent on a network communication system (for example wired or wireless Ethernet), etc. The intent is that the fault indication will be received by the person responsible for the system, when that person is located in a different location than the PV system.

14 Components

This clause of Part 1 is applicable.

Bibliography

IEC 60364-7-712, *Electrical installations of buildings – Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems*

IEC 61008-1, *Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs) – Part 1: General rules*

IEC 61727, *Photovoltaic (PV) systems – Characteristics of the utility interface*

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IEC 62116, *Test procedure of islanding prevention measures for utility-interconnected photovoltaic inverters*

EN 50438, *Requirements for the connection of micro-generators in parallel with public low-voltage distribution networks*

IEEE 1547, *Standard for Interconnecting Distributed Resources with Electric Power Systems*

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