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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

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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- withdrawn,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.

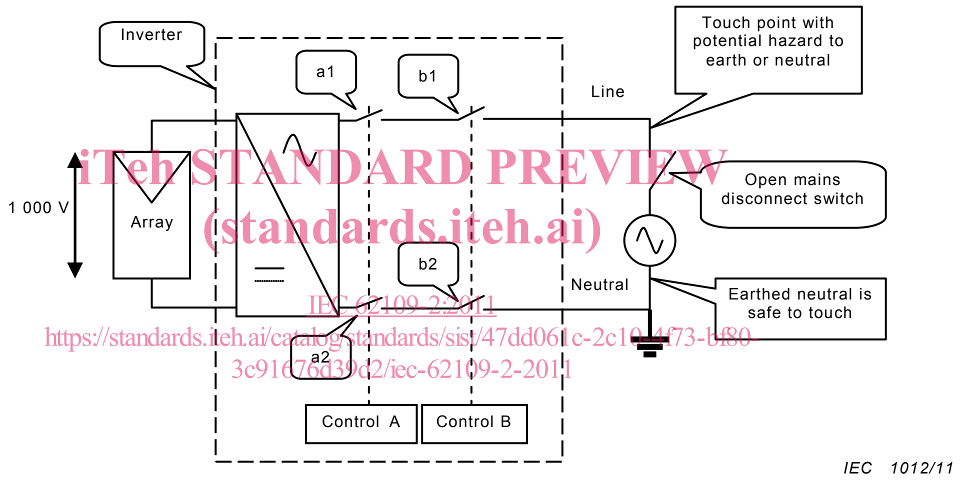

Figure 20 – Example system discussed in Note 2 above

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.