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பொதுசனக் கருத்துரைக்கான கட்டளை வரைவு

DRAFT STANDARD FOR PUBLIC COMMENT

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DRAFT SRI LANKA STANDARD SPECIFICATION FOR SAFETY OF HYBRID INVERTER FOR SOLAR PV SYSTEM

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இவ்வரைவு இலங்கைக் கட்டளையெனக் கருதப்படவோ அன்றிப் பிரயோகிக்கப்படவோ கூடாது
This draft should not be regarded or used as a Sri Lanka Standard.

විවේචන එවිය යුත්තේ:ශ්‍රී ලංකා ප්‍රමිති ආයතනය නො .17, වික්ටෝරියා පෙදෙස, ඇල්විටිගල මාවත, කොළඹ 08.
Comments to be sent to: Sri Lanka Standards Institution, No 17, Victoria Place, Elvitigala Mawatha, Colombo 08.

Draft Sri Lanka Standard Specification for

SAFETY OF HYBRID INVERTER FOR SOLAR PV SYSTEM

SLS xxxx : 2020

Gr. 7

SRI LANKA STANDARDS INSTITUTION
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Draft Sri Lanka Standard Specification for

SAFETY OF HYBRID INVERTER FOR SOLAR PV SYSTEM

FOREWORD

This Sri Lanka Standard was approved by the Sectoral Committee on Electronics Engineering and was authorized for publication as a Sri Lanka Standard by the Council of the Sri Lanka Standards Institution on xx xx xx.

~~This code of practice is written for grid connected net energy metered solar PV system to improve the safety, performance and reliability of system. Furthermore, to encourage industrial best practices from the design, installation and commissioning stagers and uptakes the solar photovoltaic systems, by giving customers confidence in the design and installation.~~
~~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 round off in accordance with **SLS 102.** 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.~~

All values given in this specification are in SI units.

In the preparation of this standard, the assistance derived from AS/NZS 5033 Installation and Safety requirements for photovoltaic array, published by Australia standard limited and Standards New Zealand and part of **IEC 62446** Grid connected photovoltaic systems – Minimum requirements for system documentation, commissioning, testing and inspection published by International Electrotechnical Committee (IEC) are gratefully acknowledged.

Scope

This Sri Lanka Standard covers the particular safety requirements relevant to d.c. to a.c. solar hybrid inverter products as well as products that perform inverter functions in addition to other functions, where the inverter is intended for use in photovoltaic power systems.

Type of operation of solar hybrid inverter covered by this standard may be grid-connected, stand-alone mode operation, or multiple modes. This hybrid inverter may be connected single or multiple photovoltaic modules in various array configurations and intended for use with batteries or other forms of energy storage as the second source of energy.

Type 1: Grid-connected solar hybrid inverter

The grid-connected inverter that is able to operate in parallel with the utility and excess electric power able to flow into the utility if the utility permits.

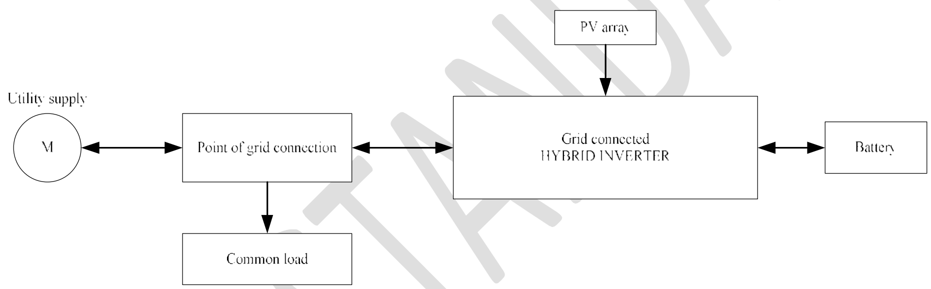


Figure 1 - Example diagram for Grid-connected hybrid inverter

Type 2: Grid interactive solar hybrid inverter

The grid-interactive inverter that is known as a grid-connected inverter and additionally able to operate in both stand-alone and parallel modes when required.

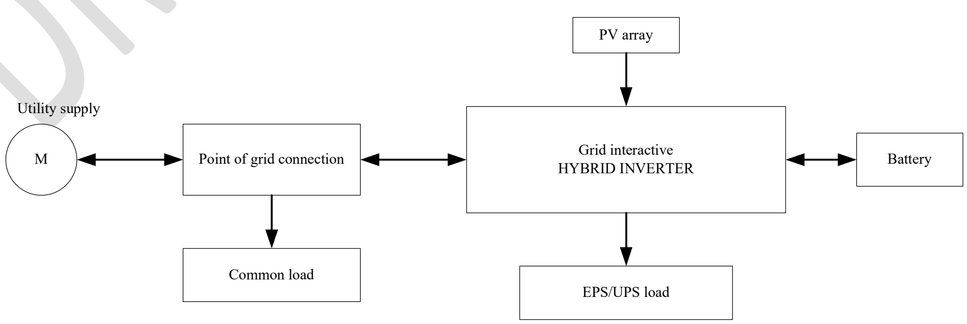


Figure 2- Example diagram for Grid interactive hybrid inverter

NOTES

1. *Type 1 and Type 2 inverters are incorporate with batteries to store your excess solar energy and allows use of stored solar energy during peak times (known as self-use, self-consumption or load-shifting).*
2. *Type 2: grid interactive solar hybrid inverter can provide electricity to essential load during a blackout time, similar to a UPS system. Wiring arrangement shall be in accordance with wiring regulation stipulated in Sri Lanka and utility requirements with two pole isolation switch. Backup power may limit how many appliances you can run at the same time (depending on the type of hybrid inverter and its battery capability).*
3. *The Grid-Interactive solar hybrid inverter shall conform to the IEC 61727 or existing national or local grid interconnection requirements that must be met.*
4. *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*

Users of this standard should be aware grid interconnection of type 1 and type 2 inverters shall meet the national or local requirements.

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

Manufacturer shall recommend the type/(s) of battery, brand names and model numbers that are suitable for their inverters considering safe operations.

This standard does not cover non-sinusoidal output waveform inverter.

The protection function may be provided as an internal device in the system. If inverters (single or multiple) have d.c SELV input and have accumulated power below 1 kW, then no mechanical disconnect (relay) is required.

This document specifies requirements to ensure safety for operation. The objective is to reduce risks of fire, electric shock, thermal, energy and mechanical hazards during use and operation and, where specifically stated, during service and maintenance.

2. REFERENCES

IECTS 61836: 2016 Solar photovoltaic energy systems – Terms, definitions and symbols.

IEC 62040-1: 2017 Uninterruptible power systems (UPS) – Part 1: Safety requirements.

IEC 62040-2: 2016 Uninterruptible power systems (UPS) – Part 2: Electromagnetic compatibility (EMC) requirements.

IEC 62040-3: 2011 Uninterruptible power systems (UPS) – Part 3: Method of specifying the performance and test requirements.

SLS 1543-1: 2016 Safety of power converters for use in photovoltaic power systems – Part 1 General requirements, this standard is equivalent to IEC 62109-1: 2010, Safety of power converters for use in photovoltaic power systems – Part 1 General requirements.

SLS 1543-2: 2016 Safety of power converters for use in photovoltaic power systems – Part 2 Particular requirements for inverters, IEC 62109-2: 2011, Safety of power converters for use in photovoltaic power systems – Part 2 Particular requirements for inverters.

DEFINITIONS

3.1 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.

NOTES

1. *Such a system is not considered to be a grounded array – see 3.2.*
2. *Examples of functional array grounding include grounding one conductor through an impedance, or only temporarily grounding the array for functional or performance reasons*
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.*

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

NOTES

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*
2. *This is not to be confused with protective earthing (equipment grounding) of the array frame*
3. *In some local installation codes, grounded arrays are allowed or required to open the array connection to earth underground-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.*

3.3 grid-connected inverter: inverter that is able to operate in parallel with the distribution or transmission system of an electrical utility

NOTE

A grid-connected inverter is also known variously as a grid-intertie or a grid-tied inverter. [SOURCE: IEC 60050-151:2001, 151-13-46]

3.4 grid-interactive inverter: grid-connected inverter that is able to operate in both stand-alone and parallel modes

NOTE

A grid-interactive inverter initiates a grid-parallel mode of operation.

3.5 inverter: electric energy converter that changes direct electric current to single-phase or polyphaser alternating current

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

NOTES

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.*
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.*

3.7 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

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

NOTE

See the notes under 3.6 above.

3.9 non-islanding inverter: inverter that ceases to energize an electricity distribution system that is out of the normal operating specifications for voltage and/or frequency

3.10 stand-alone inverter: inverter that supplies a load not connected to the distribution or transmission system of an electrical utility

NOTE

A stand-alone inverter is also known as a "battery-powered inverter".

3.11 backfeed operation: mode of operation when electric power flows from a generating system into a utility grid

NOTE

Backfeed operation arises when the generating system generates more electricity than is used by local electrical loads.

3.12 grid-connected operation: mode of operation in which a PV system is electrifying loads in parallel with a utility grid.

NOTES

1. *In a grid-connected operation, site loads will be electrified by either or both the utility or the PV system.*
2. *Electricity will be able to flow into the utility if the utility permits backfeed operation.*

3.13 grid-dependent operation: mode of operation in which a grid-connected inverter depends on the utility grid to initiate and continue the inverter's operation.

3.14 islanding operation: mode of operation for operating an island.

NOTE

Islanding operation includes maintaining frequency, voltage, power reserve, and instantaneous active and reactive power requirements.

3.15 **isolated operation:** stable and temporary operation of a discrete part of a grid.

NOTE

See also IEC 60050-603:1986, 603-04-33.

3.16 **off-grid operation:** also known as stand-alone operation 3.19.

3.17 **parallel operation:** mode of operation when a grid-connected generator is supplying electricity to the grid or site loads at the same time as a utility grid.

NOTE

Parallel operation is also known as grid-parallel operation.

3.18 **stand-alone operation:** mode of operation in which loads are electrified solely by the PV system and not in parallel with a utility grid.

4 Requirements

4.1 Environmental requirements and conditions

The manufacturer shall declare the solar hybrid inverter for the following environmental conditions:

- Environmental category: manufacture has to declare indoor / outdoor use
- Suitability for wet locations or not
- Pollution degree rating: minimum PD3
- Ingress protection (IP) rating: Minimum IP55
- Ultraviolet (UV) exposure rating, as per clause 6.4 in IEC 62109-1
- Ambient temperature 5 - 50^{0}C and relative humidity 95% ratings.

The documentation provided with the solar hybrid inverter shall include these ratings as per 5.3.1. In addition, the IP rating and other marking shall be marked on the equipment as per 5.1.4.

Compliance is shown by inspection.

4.2 Environmental categories and minimum environmental conditions

The solar hybrid inverter environmental categories are defined as follows:

NOTE
The term environmental category replaces the term "service use" used in IEC 62093 to avoid confusion between two meanings of "service" (use vs. maintenance).

4.2.1 Outdoor

The solar hybrid inverter is fully or partly exposed to direct rain, sun, wind, dust, fungus, ice, condensation, radiation to the cold night sky, etc., and to the full range of outdoor temperature and humidity. Wet location requirements apply.

4.2.2 Indoor, unconditioned

The solar hybrid inverter is fully covered by a building or enclosure to protect it from direct rain, sun, windblown dust, fungus, and radiation to the cold night sky, etc., but the building or enclosure is not conditioned in terms of temperature, humidity or air filtration, and the equipment may experience condensation. If the solar hybrid inverter is not rated for and evaluated for wet location use, then the installation instructions shall specify that the installation location must be dry, except for condensation.

4.2.3 Indoor, conditioned

The solar hybrid inverter is fully covered by a building or enclosure to fully protect it from rain, sun, windblown dust, fungus, and radiation to the cold night sky, etc., and the building or enclosure is generally conditioned in terms of temperature, humidity and air filtration. Condensation is not expected. If the solar hybrid inverter is not rated for and evaluated for wet location use, then the installation instructions shall specify that the installation location must be dry, including no expected condensation.

5. MARKING

5.1 General Marking

5.1.1 General

This clause is applicable to clause 5.1.1 in SLS 1543-1: 2016

5.1.2 Durability of markings

This clause is applicable to clause 5.1.2 in SLS 1543-1: 2016

5.1.3 Identification

This clause is applicable to clause 5.1.3 in SLS 1543-1: 2016

5.1.4 Equipment ratings

The ratings in Table 1 shall be clearly 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 1 – Inverter ratings – Marking requirements

Rating Units	**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 SLS 1543-1:2016	
[a] These terms are defined in Clause 3 of SLS 1543-1:2016.	

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.

5.1.5 Fuse identification

This clause is applicable to clause 5.1.5 in SLS 1543-1: 2016

5.1.6 Terminals, connections and controls

This clause is applicable to clause 5.1.6 in SLS 1543-1: 2016

5.1.7 Switches and circuit-breakers

This clause is applicable to clause 5.1.7 in SLS 1543-1: 2016

5.1.8 Class II equipment

This clause is applicable to clause 5.1.8 in SLS 1543-1: 2016

5.1.9 Terminal boxes for external connections

This clause is applicable to clause 5.1.9 in SLS 1543-1: 2016

5.2 Warning markings

5.2.1 Visibility and legibility requirements for warning markings

This clause is applicable to clause 5.2.1 in SLS 1543-1: 2016

5.2.2 Content for warning markings

This clause is applicable to clause 5.2.2 in SLS 1543-1: 2016

5.2.2.1 Ungrounded heatsinks and similar parts

This clause is applicable to clause 5.2.2.1 in SLS 1543-1: 2016

5.2.2.2 Hot surfaces

This clause is applicable to clause 5.2.2.2 in SLS 1543-1: 2016

5.2.2.3 Coolant

This clause is applicable to clause 5.2.2.3 in SLS 1543-1: 2016

5.2.2.4 Stored energy

This clause is applicable to clause 5.2.2.4 in SLS 1543-1: 2016

5.2.2.5 Motor guarding

This clause is applicable to clause 5.2.2.5 in SLS 1543-1: 2016

5.2.2.6 Inverters for closed electrical operating areas

Where required by 6.11.3.6an 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.

5.2.3 Sonic hazard markings and instructions

This clause is applicable to clause 5.2.3 in SLS 1543-1: 2016

5.2.4 Equipment with multiple sources of supply

This clause is applicable to clause 5.2.4 in SLS 1543-1: 2016

5.2.5 Excessive touch current

This clause is applicable to clause 5.2.5 in SLS 1543-1: 2016

5.3 Documentation

5.3.1 General

This clause is applicable to clause 5.3.1 in SLS 1543-1: 2016

5.3.2 Information related to installation

This clause is applicable to clause 5.3.2 in SLS 1543-1: 2016

5.3.2.1 Ratings

Subclause5.3.2 requires the documentation to include ratings information for each input and output. For inverters this information shall be as in Table 2 below. Only those ratings that are applicable based on the type of inverter are required.

Table 2 – Inverter ratings – Documentation requirements

Rating Units	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), orRMS[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
Protective class [a] (I, II, or III)	
Ingress protection [a] (IP) rating per SLS 1543-1:2016	

[a] These terms are defined in section 3 of SLS 1543-1:2016.

[b] The output short circuit test section in SLS 1543-1:2016 specifies the type of measurement and the required units for this rating.

5.3.2.2 Grid-interactive inverter set points

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 solar hybrid inverter or in other format such as on a website.

NOTE
Some local interconnect standards require that adjustments to such set points 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 set points shall be accessible from the hybrid inverter, 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 a.c 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 a.c mains voltage.

5.3.2.7 Systems located in closed electrical operating areas

Where required by6.11.3.6 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 Grid interactive solar hybrid inverter output circuit bonding

Where required by 8.3.10, 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 6.11.3.1 is met by requiring an RCD that is not provided integral to the inverter, as allowed by 6.11.3.4, 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 14.9.

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 6.11.2.1 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;

5.3.2.12 Array functional grounding information

Where approach a) of 6.11.2.2 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 Grid interactive solar hybrid inverter s for dedicated loads

Where the approach of 6.10.3.3 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.

5.3.3 Information related to operation

This clause is applicable to clause 5.3.3 in SLS 1543-1: 2016

5.3.4 Information related to maintenance

This clause is applicable to clause 5.3.4 in SLS 1543-1: 2016

6 METHOD OF TEST

6.1 GENERAL TEST REQUIREMENTS

Tests according to this document shall be type tests.

NOTES

1. *The requirements and tolerances in this document are related to testing of a type-test sample submitted by the manufacturer for that purpose.*
2. *Conformity of production is the responsibility of the manufacturer and can need routine tests and quality assurance in addition to type testing.*

6.2 GENERAL

This clause is applicable to clause 4.1 in SLS 1543-1: 2016

6.3 General conditions for testing

This clause is applicable to clause 4.2 in SLS 1543-1: 2016

6.4 Thermal testing

This clause is applicable to clause 4.3 in SLS 1543-1: 2016

6.5 Testing in single fault condition

6.5.1 General

This clause is applicable to clause 4.4.1 in SLS 1543-1: 2016

6.5.2 Test conditions and duration for testing under fault conditions

This clause is applicable to clause 4.4.2 in SLS 1543-1: 2016

6.5.3 Pass/fail criteria for testing under fault conditions

This clause is applicable to clause 4.4.3 in SLS 1543-1: 2016

6.5.4 Single fault conditions

6.5.4.1 Component fault tests

This clause is applicable to clause 4.4.4.1 in SLS 1543-1: 2016

6.5.4.2 Equipment or parts for short-term or intermittent operation

This clause is applicable to clause 4.4.4.2 in SLS 1543-1: 2016

6.5.4.3 Motors

This clause is applicable to clause 4.4.4.3 in SLS 1543-1: 2016

6.5.4.4 Transformer short circuit tests

This clause is applicable to clause 4.4.4.4 in SLS 1543-1: 2016

6.5.4.5 Output short circuit

This clause is applicable to clause 4.4.4.5 in SLS 1543-1: 2016

6.5.4.6 Backfeed current test for equipment with more than one source of supply

This clause is applicable to clause 4.4.4.6 in SLS 1543-1: 2016

6.5.4.7 Output overload

This clause is applicable to clause 4.4.4.7 in SLS 1543-1: 2016

6.5.4.8 Cooling system failure

This clause is applicable to clause 4.4.4.8 in SLS 1543-1: 2016

6.5.4.9 Heating devices

This clause is applicable to clause 4.4.4.9 in SLS 1543-1: 2016

6.5.4.10 Safety interlock systems

This clause is applicable to clause 4.4.4.10 in SLS 1543-1: 2016

6.5.4.11 Reverse d.c. connections

This clause is applicable to clause 4.4.4.11 in SLS 1543-1: 2016

6.5.4.12 Voltage selector mismatch

This clause is applicable to clause 4.4.4.12 in SLS 1543-1: 2016

6.5.4.13 Mis-wiring with incorrect phase sequence or polarity

This clause is applicable to clause 4.4.4.13 in SLS 1543-1: 2016

6.5.4.14 Printed wiring board short-circuit test

This clause is applicable to clause 4.4.4.14 in SLS 1543-1: 2016

6.5.4.15 Fault-tolerance of protection for grid-interactive inverters

6.5.4.15.1 Fault-tolerance of residual current monitoring

Where protection against hazardous residual currents according to 6.11.3.5 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 with14.9 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 SLS 1543-1:2016. 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 14.9 disconnects from the mains, and does not re-connect after any sequence of removing and reconnecting PV power, a.c power, or both, or

b) the inverter continues to operate, passes testing in accordance with 6.11.3.5 showing that the residual current monitoring system functions properly under the single fault condition, and indicates a fault in accordance with 14.9or

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, a.c power, or both, and indicates a fault in accordance with 14.9.

6.5.4.15.2 Fault-tolerance of automatic disconnecting means

6.5.4.15.2.1 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.

6.5.4.15.2.2 Design of insulation or separation

The design of the basic insulation or simple separation referred to in 6.5.4.15.2.1shall 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 8.3.7;
- the mains shall be assumed to be disconnected;
- the provisions of clause 7.3.7.1.2 g) of SLS 1543-1: 2016 may be applied if the design incorporates means to reduce impulse voltages, and where required by clause 7.3.7.1.2 of SLS 1543-1: 2016, monitoring of such means;
- in determining the clearance based on working voltage in 8.3.7, the values of column 3 of Table 13 of SLS 1543-1: 2016 shall be used.

NOTES

1. *These requirements are intended to protect workers who are servicing the a.c 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.*

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 a.c main with a n earthed neutral. See Figure 3 below.*

- Subclause6.5.4.15.2.1requires 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 3 below) in the ungrounded a.c 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 SLS 1543-1: 2016, the impulse voltage withstands rating for a PV circuit system voltage of 1000 V d.c is 4 464 V. From Table 13 of SLS 1543-1: 2016, 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.

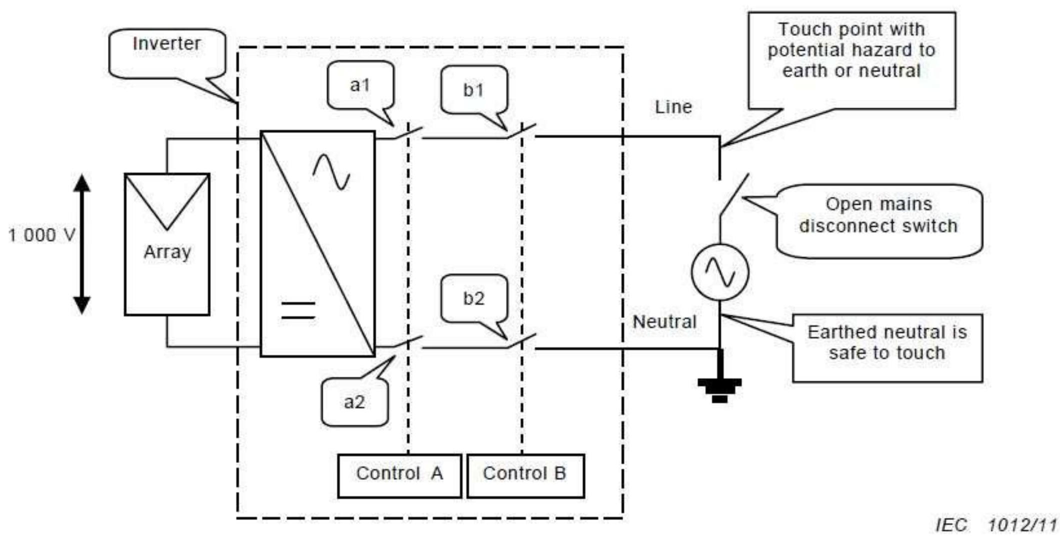


Figure 3 – Example system discussed in Note 2 above

6.5.4.15.2.3 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 14.9.

Compliance with 6.5.4.15.2.1through 6.5.4.15.2.3 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 SLS 1543-1:2016, 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 14.9.

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.

6.5.4.16 Cooling system failure – Blanketing test

In addition to the applicable tests of subclause6.5.4.8 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 subclause6.5.3 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 SLS 1543-1: 2016, but not for blanketing of a heatsink.

Compliance is checked by the following test, performed in accordance with the requirements of subclause6.5.2 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 subclause6.5.3.2. 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.

6.6 Humidity preconditioning

This clause is applicable to clause 4.5 in SLS 1543-1: 2016

6.7 Backfeed voltage protection

This clause is applicable to clause 4.6 in SLS 1543-1: 2016

6.8 Electrical ratings tests

6.8.1 Input ratings

This clause is applicable to clause 4.7.1 in SLS 1543-1: 2016

6.8.2 Output ratings

This clause is applicable to clause 4.7.2 in SLS 1543-1: 2016

6.9 Utility compatibility

The quality of power provided by the PV system for the on-site a.c loads and for power delivered to the utility is governed by practices and standards on voltage, flicker, frequency, harmonics and power factor. Deviation from these standards represents out-of-bounds conditions and may require the PV system to sense the deviation and properly disconnect from the utility system.

All power quality parameters (voltage, flicker, frequency, harmonics, and power factor) must be measured at the utility interface / point of grid connection unless otherwise specified.

NOTE Balancing phase currents in multiphase systems is desirable.

6.9.1 Voltage, current and frequency

The PV system a.c voltage, current and frequency shall be compatible with the utility system.

6.9.2 Normal voltage operating range

Utility-interconnected PV systems do not normally regulate voltage; they inject current into the utility. Therefore, the voltage operating range for PV inverters is selected as a protection function that responds to abnormal utility conditions, not as a voltage regulation function.

6.9.3 Flicker

The operation of the PV system should not cause voltage flicker in excess of limits stated in the relevant sections of IEC 61000-3-3 for systems less than 16 A or IEC 61000-3-5 for systems with current of 16 A and above.

6.9.4 DC injection

The PV system shall not inject d.c current greater than 0.5 % of the rated inverter output current, into the utility a.c interface under any operating condition.

6.9.5 Normal frequency operating range

The PV system shall operate in synchronism with the utility system, and within the frequency trip limits defined in 6.9.8.2.

6.9.6 Harmonics and waveform distortion

Low levels of current and voltage harmonics are desirable; the higher harmonic levels increase the potential for adverse effects on connected equipment.

Acceptable levels of harmonic voltage and current depend upon distribution system characteristics, type of service, connected loads/apparatus, and established utility practice.

The PV system output should have low current-distortion levels to ensure that no adverse effects are caused to other equipment connected to the utility system.

Total harmonic current distortion shall be less than 5 % at rated inverter output. Each individual harmonic shall be limited to the percentages listed in Table 3.

Even harmonics in these ranges shall be less than 25 % of the lower odd harmonic limits listed.

Table 3– Current distortion limits

Odd harmonics	Distortion limit
3rd through 9th	Less than 4.0 %
11th through 15th	Less than 2.0 %
17th through 21st	Less than 1.5 %
23rd through 33rd	Less than 0.6 %

Even harmonics	Distortion limit
2nd through 8th	Less than 1.0 %
10th through 32nd	Less than 0.5 %

NOTE

Testing harmonics is very problematic, since voltage distortion may lead to enhanced current distortion. The harmonic current injection should be exclusive of any harmonic currents due to harmonic voltage distortion present in the utility grid without the PV system connected. Type tested inverters meeting the above requirements should be deemed to comply without further testing.

6.9.7 Power factor

The PV system shall have a lagging power factor greater than 0.9 when the output is greater than 50% of the rated inverter output power.

NOTES

1. *Specially designed systems that provide reactive power compensation may operate outside of this limit with utility approval.*
2. *Most PV inverters designed for utility-interconnected service operate close to unity power factor.*

6.9.8 Personal safety and equipment protection

This Clause provides information and considerations for the safe and proper operation of the utility-connected PV systems.

NOTE

1. *The protection function may be provided as an internal or external device in the system*
2. *IEC 60364-5-55 or national or local codes may be applicable.*

6.9.8.1 Loss of utility voltage

To prevent islanding, a utility connected PV system shall cease to energize the utility system from a de-energized distribution line irrespective of connected loads or other generators within specified time limits.

A utility distribution line can become de-energized for several reasons. For example, a substation breaker opening due to fault conditions or the distribution line switched out during maintenance.

If inverters (single or multiple) have d.c SELV input and have accumulated power below 1 kW then no mechanical disconnect (relay) is required.

6.9.8.2 Over / Under voltage and frequency

Abnormal conditions can arise on the utility system that require a response from the connected photovoltaic system. This response is to ensure the safety of utility maintenance personnel and the general public, as well as to avoid damage to connected equipment, including the photovoltaic system. The abnormal utility conditions of concern are voltage and frequency excursions above or below the values stated in this Clause, and the complete disconnection of the utility, presenting the potential for a distributed resource island.

6.9.8.2.1 Over/under voltage

When the interface voltage deviates outside the conditions specified in Table 4, the photovoltaic system shall cease to energize the utility distribution system. This applies to any phase of a multiphase system.

All discussions regarding system voltage refer to the local nominal voltage.

The system shall sense abnormal voltage and respond. The following conditions should be met, with voltages in RMS and measured at the point of utility connection.

Table 4 – Response to abnormal voltages

Voltage (at point of utility connection)	Maximum trip time*
$V < 0.5 \times V_{nominal}$	0.1 s
$50\ \% \leq V < 85\ \%$	2.0 s
$85\ \% \leq V \leq 110\ \%$	Continuous operation
$110\ \% < V < 135\ \%$	2.0 s
$135\% \leq V$	0.05 s
* Trip time refers to the time between the abnormal condition occurring and the inverter ceasing to energize the utility line. The PV system control circuits shall actually remain connected to the utility to allow sensing of utility electrical conditions for use by the "reconnect" feature.	

The purpose of the allowed time delay is to ride through short-term disturbances to avoid excessive nuisance tripping. The unit does not have to cease to energize if the voltage returns to the normal utility continuous operation condition within the specified trip time.

NOTE
The voltage drop between the inverter terminals and the point of connection with the utility should be taken into consideration.

6.9.8.2.2 Over/under frequency

When the utility frequency deviates outside the specified conditions the photovoltaic system shall cease to energize the utility line. The unit does not have to cease to energize if the frequency returns to the normal utility continuous operation condition within the specified trip time.

When the utility frequency is outside the range of ±0.5 Hz, the system shall cease to energize the utility line within 0.2 s. The purpose of the allowed range and time delay is to allow continued operation for short-term disturbances and to avoid excessive nuisance tripping in weak-utility system conditions.

6.9.8.3 Islanding protection

This islanding protection test in accordance with IEC 62116: 2014
The PV system must cease to energize the utility line less than 500 ms of loss of utility.

NOTE
The issues of non-islanding inverter are the subject of another standard under consideration.

6.9.8.4 Response to utility recovery

Following an out-of-range utility condition that has caused the photovoltaic system to cease energizing, the photovoltaic system shall not energize the utility line less than 180 s after the utility service voltage and frequency have recovered to within the specified ranges.

NOTE
The energizing delay is dependent on local conditions.

6.9.8.5 Earthing

The utility interface equipment shall be earthed / grounded in accordance with IEC 60364-7-712.

6.9.8.6 Short circuit protection

The photovoltaic system shall have short-circuit protection in accordance with IEC 60364-7-712.

6.9.8.7 Isolation and switching

A method of isolation and switching shall be provided in accordance with IEC 60364-7-712.

6.10 SPECIFIC TESTING REQUIREMENTS FOR GRID INTERACTIVE SOLAR HYBRID INVERTER

6.10.1 Measurement requirements for a.c output ports for grid interactive solar hybrid inverter

Measurements of the a.c output voltage and current on a grid interactive solar hybrid inverter shall be made with a meter that indicates the true RMS value.

6.10.2 grid interactive solar hybrid inverter a.c output voltage and frequency

6.10.2.1 General

The a.c output voltage and frequency of a grid interactive solar hybrid inverter operating in stand-alone mode, shall comply with the requirements stipulated in 6.10.2.2 to 6.10.2.5

6.10.2.2 Steady state output voltage at nominal d.c input

The steady-state a.c 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 d.c input voltage.

Compliance is checked by measuring the a.c 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 a.c output voltage is measured after any transient effects from the application or removal of the load have ceased).

6.10.2.3 Steady state output voltage across the d.c input range

The steady-state a.c 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 d.c input voltage.

Compliance is checked by measuring the a.c 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 d.c input voltage and at the maximum rated d.c input voltage. The a.c output voltage is measured after any transient effects from the application or removal of the load have ceased.

6.10.2.4 Load step response of the output voltage at nominal d.c input

The a.c 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 d.c input voltage.

Compliance is checked by measuring the a.c 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.

6.10.2.5 Steady state output frequency

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

Compliance is checked by measuring the a.c 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 d.c input voltage and at the maximum rated d..c input voltage. The a.c output frequency is measured after any transient effects from the application or removal of the load have ceased.

6.10.3 Grid interactive solar hybrid inverter output voltage waveform

6.10.3.1 General

The a.c output voltage waveform of a grid interactive solar hybrid inverter operating in stand-alone mode, shall comply with the requirements in 6.10.3.2 for sinusoidal outputs, or with the dedicated load requirements in 6.10.3.5.

6.10.3.2 Sinusoidal output voltage waveform requirements

The a.c output waveform of a sinusoidal output grid interactive solar hybrid 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 d.c 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.

6.10.3.3 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 6.10.3.2.

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, disoperation of control circuits, particularly protective circuitry, etc.

The inverter shall be marked with symbols 9 and 15 of Table C.1 of SLS 1543-1: 2016.

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

6.10.4 Grid interactive solar hybrid inverter – Load transfer test

A grid interactive solar hybrid inverter with a transfer switch to transfer a.c loads from the mains or other a.c 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.

6.10.5 Grid interactive solar hybrid inverter Transfer to bypass

This test shall be performed for UPS port available grid interactive solar hybrid inverter with bypass capability, particularly in the case of an electronic bypass switch.

The test shall be conducted with rated load applied to the output of the UPS port available grid interactive solar hybrid inverter. By failure simulation or output overload, the load shall be transferred to the bypass automatically and then back to the inverter either automatically or operator controlled when failure simulation or output overload is removed.

The output voltage transient shall be measured and comply with the manufacturer's declared limits. The phase angle between the bypass and the solar hybrid inverter shall also be observed during this operation.

NOTE
This test may be performed in conjunction with the full load test of clause 6.2.2.5 of IEC 62040-3.

6.10.6 Grid interactive solar hybrid inverter Backfeed protection

A UPS port available grid interactive solar hybrid inverter shall prevent hazardous voltage or hazardous energy from being present on the grid interactive inverter input a.c terminals after interruption of the grid power.

No shock hazard shall exist at a.c input terminals when measured 1 s after de-energization of a.c input for pluggable UPS port available grid interactive solar hybrid inverter, or 15 s for permanently connected UPS port available grid interactive solar hybrid inverter.

For permanently connected UPS port available grid interactive solar hybrid inverter, backfeed protection may be implemented external to the grid interactive solar hybrid inverter with the use of an a.c input line isolation device.

In this case, the backfeed protection requirement applies to the input terminals of the isolation device. The grid interactive solar hybrid inverter supplier shall provide or specify a suitable isolating device which shall include additional labelling and instructions in accordance with 6.4.3.101 in IEC 62040-1.

Compliance is checked by inspection of the equipment and relevant circuit diagram, and by simulating fault conditions in accordance with 5.2.3.101 in IEC 62040-1.

When an air gap is employed for backfeed protection, the provision of IEC 62477-1:2012, Table 10 and Table 11 for creepage and clearance distances applies in addition to the following.

a) Subject to confirmation from the manufacturer, the grid interactive inverter UPS output, in stored energy mode, may be considered a transient free circuit of overvoltage category I (for this purpose identify the overvoltage category I value in IEC 62477-1:2012, Table 9, by using the appropriate RMS system output voltage). An impulse voltage withstand test is not required since there is no transient overvoltage present when the a.c main input supply is not available. Therefore, the overvoltage category values apply without an impulse test.

b) The creepage and clearance distances shall meet the requirements for pollution degree 2 (see IEC 62477-1:2012, Table 10 and Table 11).

c) Reinforced or equivalent insulation of the grid interactive inverter UPS output port to the grid interactive inverter input port applies if during stored energy mode of operation not all input poles are isolated by the backfeed protection device. In all other cases, basic insulation is acceptable. Impulse withstand voltage is not required since there is no impulse when the a.c main input supply is not available. Therefore, the pollution degree values apply without an impulse test.

NOTES

1. *A contactor is an example of an isolation device presenting an air gap.*
2. *One method of obtaining insulation equivalent to reinforced insulation is to combine an air gap meeting the basic insulation requirements and a solid-state power isolation device(s) as described in 5.2.3.101.5.*

Compliance is checked by inspection

6.11 ADDITIONAL TESTS FOR GRID INTERACTIVE HYBRID INVERTER

6.11.1 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 5 for the applicable combination of inverter isolation and array grounding.

Table 5 – Requirements based on inverter isolation and array grounding

Array grounding	**Ungrounded[a] or functionally grounded**	**Ungrounded or functionally grounded**	**Grounded**
Inverter isolation	**Non-isolated**	**Isolated**	**Isolated**
Minimum inverter isolation requirements	Not applicable	Basic or reinforced [b] insulation and Leakage current type testing per 6.11.3.2 (shock hazard) and 6.11.3.3 (fire hazard) to determine the requirements for array ground insulation resistance and array residual current detection, below	
Array ground insulation resistance measurement	Before starting operation, per 6.11.2.1 or 6.11.2.2 Action on fault: indicate a fault in accordance with 14.9, and do not connect to the mains	Before starting operation, per 6.11.2.1 or 6.11.2.2 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 14.9, For inverters with isolation not complying with the above minimum	Not required [d]

		leakage current values, indicate a fault in accordance with 14.9, and do not connect to the mains	
Array residual current detection	Either a) 30 mA RCD[c] between the inverter and the mains per 6.11.3.4, or b) monitoring for both continuous excessive residual current per 6.11.3.5.1 a) and excessive sudden changes per 6.11.3.5.1 b) Action on fault: shut down the inverter, disconnect from the mains, and indicate a fault in accordance with 14.9,	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 per6.11.3.2 require monitoring for sudden changes in residual current per 6.11.3.5.1 b) or use of an RCD per 6.11.3.4 Inverters with isolation not complying with the leakage current limits for fire hazard per6.11.3.3 require monitoring for excessive continuous residual current per 6.11.3.5.1 a) or use of an RCD per 6.11.3.4 Action on fault: shut down the inverter, disconnect from the mains, and indicate a fault in accordance with 14.9,	
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 6.11.3.4. 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 5 above indicates "Not required" for this technique on			

6.11.2 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.

6.11.2.1 Array insulation resistance detection for inverters for ungrounded arrays

Inverters for use with ungrounded arrays shall have means to measure the d.c 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 $R = (V_{MAX\ PV}/30\ mA)$ ohms, the inverter:

- for isolated inverters, shall indicate a fault in accordance with 14.9, (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 5, shall indicate a fault in accordance with 14.9, 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 a.c and d.c components of the current, with a bandwidth of at least 2 kHz.

The inverter shall be connected to PV and a.c sources as specified in the reference test conditions in SLS 1543-1: 2016, 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 14.9 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 d.c 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.

6.11.2.2 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 $R = (V_{\text{MAX PV}}/30\text{ mA})$ 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 a.c 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 6 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 5, it shall also disconnect from the mains. inverter may attempt to resume normal operation if the array insulation resistance has recovered to a value higher than the limit in 6.11.2.1.

NOTE

For the inverter to make the measurement of array insulation resistance and meet the limit in 6.11.2.1, 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 6.11.3.5.3.

c) The inverter shall have means to measure the d.c insulation resistance from the PV in putto ground before starting operation, in accordance with 6.11.2.1.

6.11.3 Array residual current detection

6.11.3.1 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 6.11.3.4 or by monitoring for sudden changes in residual current per 6.11.3.5, 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 6.11.3.2.

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 6.11.3.4 or by monitoring for continuous excessive residual current per 6.11.3.5, 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 6.11.3.3.

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.

6.11.3.2 30 mA touch current type test for isolated inverters

Compliance with the 30 mA limit in 6.11.3.1 is tested with the inverter connected and operating under reference test conditions, except that the d.c 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 5.

NOTES

1. *For convenience, IEC 60990 test figure 4 is reproduced in Annex H of SLS 1543-1: 2016.*

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 invert under test).*

6.11.3.3 Fire hazard residual current type test for isolated inverters

Compliance with the 300 mA or 10 mA per kVA limit in 6.11.3.1 is tested with the inverter connected and operating under reference test conditions, except that the d.c 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 a.c and d.c components of the current, with a bandwidth of at least 2 kHz.

The current is recorded and compared to the limit in 6.11.3.1, to determine the requirements for array ground insulation resistance and array residual current detection in Table 5.

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 inverter under test).

6.11.3.4 Protection by application of RCD's

The requirement for additional protection in 6.11.3.1 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 SLS 1543-1:2016. 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.

6.11.3.5 Protection by residual current monitoring

6.11.3.5.1 General

Where required by Table 5, 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 5 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 14.9 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 6.11.2.

b) Sudden changes in residual current: The inverter shall disconnect from the mains within the time specified in Table 6 and indicate a fault in accordance with 14.9, if a sudden increase in the RMS residual current is detected exceeding the value in the table.

Table 6 – 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

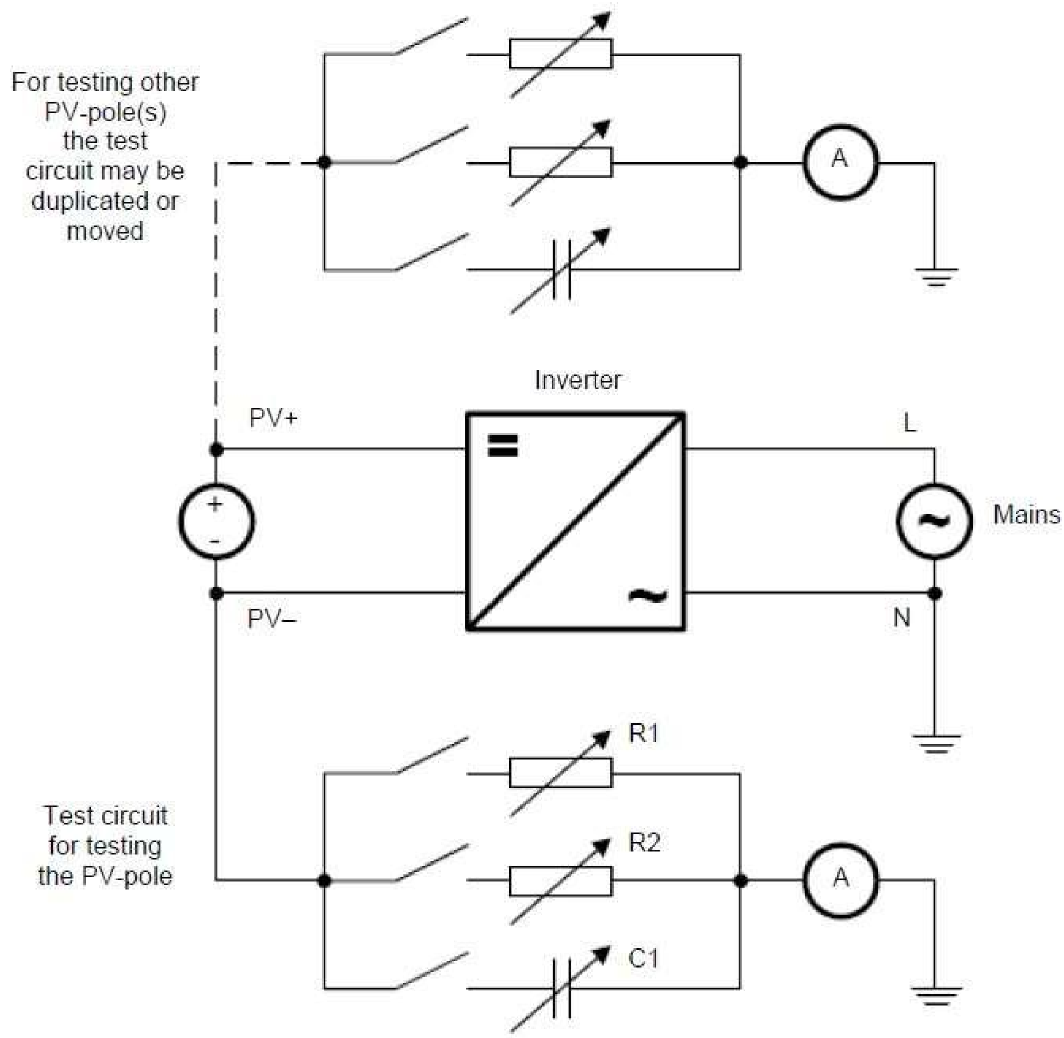
These values of residual current and time are based on the RCD standard IEC 61008-1.

Exceptions:

- monitoring for the continuous condition in a) is not required for an inverter with isolation complying with 6.11.3.3;
- monitoring for the sudden changes in b) is not required for an inverter with isolation complying with 6.11.3.2.

The inverter may attempt to re-connect if the array insulation resistance meets the limit in 6.11.2.

Compliance with a) and b) is checked by the tests of 6.11.3.5.2 and 6.11.3.5.3 respectively. Compliance with the values of current shall be determined using an RMS meter that responds to both the a.c and d.c components of the current, with a bandwidth of at least 2 kHz. An example of a test circuit is given in Figure 4 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.

Figure 4 – Example test circuit for residual current detection testing

6.11.3.5.2 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

6.11.3.5.3 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 6.11.3.5.1 b) to be tested (e.g. 45 mA for the30 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 6.

Steps a) and b) shall then be repeated for the 60 mA and 150 mA values and times in Table 6.

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 a.c 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 a.c 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.

6.11.3.6 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 6.11.2.1, 6.11.2.2, 6.11.3.2, 6.11.3.4, and 6.11.3.5.1 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.

7 Environmental requirements and conditions

This clause is applicable to clause 6 in SLS 1543-1: 2016

8 Protection against electric shock and energy hazards

8.1 General

This clause is applicable to clause 7.1 in SLS 1543-1: 2016

8.2 Fault conditions

This clause is applicable to clause 7.2 in SLS 1543-1: 2016

8.3 Protection against electric shock

8.3.1 General

This clause is applicable to clause 7.3.1 in SLS 1543-1: 2016

8.3.2 Decisive voltage classification

This clause is applicable to clause 7.3.2 in SLS 1543-1: 2016

8.3.3 Protective separation

This clause is applicable to clause 7.3.3 in SLS 1543-1: 2016

8.3.4 Protection against direct contact

This clause is applicable to clause 7.3.4 in SLS 1543-1: 2016

8.3.5 Protection in case of direct contact

This clause is applicable to clause 7.3.5 in SLS 1543-1: 2016

8.3.6 Protection against indirect contact

This clause is applicable to clause 7.3.6 in SLS 1543-1: 2016

8.3.7 Insulation including clearance and creepage distances

This clause is applicable to clause 7.3.7 in SLS 1543-1: 2016

8.3.8 Residual Current Detection (RCD) or Monitoring (RCM) device compatibility

This clause is applicable to clause 7.3.8 in SLS 1543-1: 2016

8.3.9 Protection against shock hazard due to stored energy

This clause is applicable to clause 7.3.9 in SLS 1543-1: 2016

8.3.10 Additional requirements for grid interactive solar hybrid inverter s

Depending on the supply earthing system that a grid interactive solar hybrid 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 SLS 1543-1: 2016, 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 8. The documentation for the inverter shall indicate that the output is floating as per 5.3.2.8.

8.3.11 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 SLS 1543-1:2016

8.4 Protection against energy hazards

This clause is applicable to clause 7.4 in SLS 1543-1: 2016

8.5 Electrical tests related to shock hazard

This clause is applicable to clause 7.5 in SLS 1543-1: 2016

9 Protection against mechanical hazards

This clause is applicable to clause 8 in SLS 1543-1: 2016

10 Protection against fire hazards

10.1 Resistance to fire

This clause is applicable to clause 9.1 in SLS 1543-1: 2016

10.2 Limited power sources

This clause is applicable to clause 9.2 in SLS 1543-1: 2016

10.3 Short-circuit and overcurrent protection

10.3.1 General

This clause is applicable to clause 9.3.1 in SLS 1543-1: 2016

10.3.2 Number and location of overcurrent protective devices

This clause is applicable to clause 9.3.2 in SLS 1543-1: 2016

10.3.3 Short-circuit co-ordination (backup protection

This clause is applicable to clause 9.3.3 in SLS 1543-1: 2016

10.3.4 Inverter backfeed current onto the array

The backfeed current testing and documentation requirements in SLS 1543-1: 2016 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 2.

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.

11 Protection against sonic pressure hazards

This clause is applicable to clause 10 in SLS 1543-1: 2016

12 Protection against liquid hazards

This clause is applicable to clause 11 in SLS 1543-1: 2016

13 Protection against Chemical hazards

This clause is applicable to clause 12 in SLS 1543-1: 2016

14 Physical requirements

14.1 Handles and manual controls

This clause is applicable to clause 13.1 in SLS 1543-1: 2016

14.2 Securing of parts

This clause is applicable to clause 13.2 in SLS 1543-1: 2016

14.3 Provisions for external connections

This clause is applicable to clause 13.3 in SLS 1543-1: 2016

14.4 Internal wiring and connections

This clause is applicable to clause 13.4 in SLS 1543-1: 2016

14.5 Openings in enclosures

This clause is applicable to clause 13.5 in SLS 1543-1: 2016

14.6 Polymeric materials

This clause is applicable to clause 13.6 in SLS 1543-1: 2016

14.7 Mechanical resistance to deflection, impact, or drop

This clause is applicable to clause 13.7 in SLS 1543-1: 2016

14.8 Thickness requirements for metal enclosures

This clause is applicable to clause 13.8 in SLS 1543-1: 2016

14.9 Fault indication

Where this standard 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.

15 Components

This clause is applicable to clause 14 in SLS 1543-1: 2016