

Installation Requirements



Installation and inspection of Grid-connected PV systems July 2011 (no battery storage)



This document has been prepared by Energy Safe Victoria to provide guidance for electrical contractors and licensed electrical inspectors for the installation and inspection of grid-connected PV systems without battery storage; this document contains extracts from the relevant Regulations, standards and Victorian Electricity Distributors Service and Installation rules along with proposed changes from Standards Australia EL-42 committee. There may be additional advice from the Clean Energy Council.

Standards and regulations for installation

The following standards and regulations **shall** be complied with where applicable.

Electrical Safety Act 1998

Electricity Safety (Installations) Regulations 2009

Victorian Distributors Service and Installation Rules 2011

AS/NZS 3000:2007 Wiring Rules

AS/NZS 3008.1.1:2009 Electrical Installations-Selection of cables

AS/NZS 4777.1:2005 Grid connection of energy systems via Inverters –Installation requirements

AS/NZS 4777.2:2005 Grid connection of energy systems via Inverters –Inverter requirements

AS/NZS 4777.3:2005 Grid connection of energy systems via Inverters –Grid protection requirements

What part of the Grid connected PV System is considered to be prescribed electrical installation work?

Those parts of the generation system operating at or above 120 Volt DC, cables installed between panels and between the array and inverter and the AC cables installed between the inverter and the switchboard to which the generation system is connected along with all the required isolation and protection devices, are prescribed electrical installation work.

For the purpose of section 45 of the Electricity Safety Act 1998, *prescribed electrical Installation work* means work on all or any part of the following electrical installations if they ordinarily operate at low voltage or exceeding low voltage.

- (f) Wiring systems, switchgear, controlgear and accessories installed to provide control and protection of generation systems (excluding stand alone power systems with a power rating that is less than 500 volt-amperes)

The following activities are considered to be prescribed electrical installation work;

Adding panels to an existing solar grid connected PV where the open circuit voltage (Voc Array) exceeds Extra Low Voltage.

Upgrading the inverter due to increase in generation capacity.

Changing the type of inverter i.e. isolated to non-isolated.

The replacement of one component part of prescribed electrical installation work “like to like” such as an inverter or isolator can be entered on a non-prescribed certificate without the mandatory inspection.

Note: like for like in the case of the replaced inverter means – “the same brand and model”

Reference – Electricity Safety (Installations) Regulations 2009 – Regulation 238(3)

Voltage

Differences in potential normally existing between conductors and conductors and earth as follows:

Extra Low Voltage: not exceeding 50 V AC or 120 V ripple-free DC

Low voltage: Exceeding extra-low voltage, but not exceeding 1000 V AC or 1500 V DC

High Voltage: Exceeding Low-voltage.

Reference - AS/NZS 3000:2007 Amd Clause 1.4.98 Voltage

What is Class II equipment (double insulated)

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

Equipment may be one of the following types:

- (a) Equipment having durable and substantially continuous enclosures of insulating material which envelops all metal parts, with the exception of small parts, such as nameplates, screws and rivets, which are isolated from live parts by insulation at least equivalent to reinforced insulation; such equipment is called insulation-encased Class II equipment.
- (b) Equipment having a substantially continuous metal enclosure, in which double insulation is used throughout, except for those parts where reinforced insulation is used, because the application of double insulation is manifestly impracticable; such equipment is called metal-encased Class II equipment.
- (c) Equipment that is a combination of the types described in Items (a) and (b).

NOTES:

1. *The enclosure of insulation-encased Class II equipment may form part of the whole of the supplementary insulation or of the reinforced insulation.*
2. *If the equipment with double insulation or reinforced insulation throughout has an earthing terminal or earthing contact, it is considered to be of Class I construction.*
3. *Class II equipment may be provided with means for maintaining the continuity of protective circuits, insulated from accessible conductive parts by double insulation or reinforced insulation.*
4. *Class II equipment may have parts operating at SELV.*

Reference – AS/NZS 5033 Clause 1.4.8 Class II equipment

What is a separated circuit?

Separated low voltage

A low voltage system that is electrically separated from earth and from other systems in such a way that a single fault cannot give rise to the risk of electric shock

ELECTRICAL SEPARATION (ISOLATED SUPPLY)

The expression 'electrical separation' has the same meaning as 'isolated supply'. 'Electrical separation' is used throughout this document.

Several methods of protection against electric shock arising from indirect contact are recognised by Clause 1.5.5 of AS/NZS 3000:2007. These methods include that of protection by electrical separation of the supply. Protection by electrical separation is an alternative to other recognised methods and is intended, in an individual circuit, to prevent shock current through contact with exposed conductive parts that might be energized by a fault in the basic insulation of that circuit.

Protection by electrical separation shall be afforded by compliance with Clauses 7.4.2 to 7.4.4, of AS/NZS 3000:2007 and with —

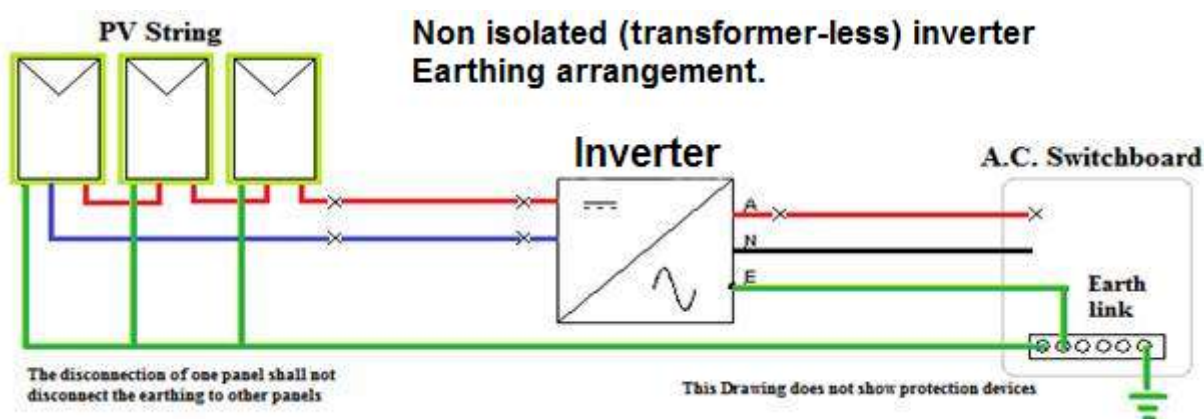
- (a) Clause 7.4.5 of AS/NZS 3000:2007 for a supply to one item of equipment; or
- (b) Clause 7.4.6 of AS/NZS 3000:2007 for a supply to more than one item of equipment.

NOTE: Figure 7.7 of AS/NZS 3000:2007 provides an illustration of a separated supply to single and multiple items of equipment.

Reference – AS/NZS 3000:2007 Clause 7.4

Do the exposed metallic parts of the solar array require be earthed or equipotential bonded?

A solar generation system with a non-isolated (transformer-less) inverter requires the metallic frames and conductive structural supports of the PV arrays to be earthed in accordance AS/NZS 3000:2007 with the requirements of a protective earthing conductor. This shall be achieved by connecting the earthing conductor with a minimum cross-sectional area of 4mm² directly or via the inverter to the installations earthing system.



The earthing requirements of other solar generation systems shall be determined by following figure 5.9 of AS/NZS 5033:2005 “PV array framework earthing decision tree”.

Equipotential bonding or protective earthing is intended to minimize the risks associated with the occurrence of voltage differences between exposed conductive parts of electrical equipment and extraneous conductive parts.

Reference - AS/NZS 5033:2005 Clause 5.3

All PV array system bonding conductors shall comply with the material, type, insulation, identification; installation and connection requirements specified in AS/NZS 3000 but shall not have a cross-sectional area less than 4mm².

Reference - AS/NZS 3000:2007 Clause 5.6.3.2

Where the solar supply is connected to a sub-board the protective earth between the main switchboard and sub-board may be of a cross-sectional area less than 4mm².

Reference – ruling from EL 001 committee - AS/NZS 3000:2007

Does the interconnecting wiring between each PV module require mechanical and IP protection?

Yes - the installation of wiring associated with PV array systems (*operating at ELV or LV*) shall be installed in accordance with AS/NZS 3000 except where varied by the additional requirements of AS/NZS 4777 Series & AS/NZS 5033.

Reference – Clause 3.1 of AS/NZS 5033

Clauses related to the wiring connecting panels and arrays

Voc Array (open circuit voltage at standard test condition) - shall not exceed the maximum allowed operating voltage of the PV modules (as specified by the manufacturer).

Reference – Clause 3.2 of AS/NZS 5033

Extra Low voltage - Segmentation (disconnection requirements)

Reference – Clause 2.5.4 of AS/NZS 5033

PV array wiring - protection and installation

Reference – Clause 3.3 of AS/NZS 5033

Wiring loops - installation

Reference - Clause 3.3.2 of AS/NZS 5033

String wiring - installation

Reference – Clause 3.3.3 of AS/NZS 5033

IP rating of the enclosure and cable entries

Reference – Clause 3.3.4 of AS/NZS 5033

PV array and PV sub-array junction boxes locations

Reference – Clause 3.3.5 of AS/NZS 5033



Do I need to install an isolating device at the PV array location that can isolate the DC cable to the inverter?

Yes - each electricity generation system shall be provided with an isolating switch, in accordance with AS/NZS 3000:2007, Clause 2.3.2.2 that —

- shall be installed adjacent to, or on, the electricity generation system so that a person operating the switch has a clear view of any person working on the electricity generation system;
- shall be DC rated, double pole;
- may be combined with overcurrent protection required by Clause 7.3.5.1 of AS/NZS 3000:2007;
- shall be under manual control only; and
- shall not be capable of being overridden or bypassed by programmable control systems or the like.

Exception - the internal isolation arrangements for systems, in accordance with AS 4509.1 or AS 4777, are deemed to satisfy these requirements.

Reference - Clause 7.3.4 of AS/NZS 3000:2007

Each DC solar supply cable shall be capable of being isolated at the PV array and be appropriately rated (*rated for current, voltage and IP*). The installation of the isolation device is mandatory so that emergency services can disconnect the supply under emergency conditions.

Reference- Electrical Inspectors Guidance notes March-2010

Are the conductors installed between the PV array and the main switchboard classified as consumer's mains?

Yes – the conductors between the output terminals of an electricity generating system that provides another source of electrical energy within the installation and the switchboard where they connect are consumers mains.

Consumers mains - those conductors between the point of supply and the main switchboard.

Reference – AS/NZS 3000:2007 Clause 1.4.33

Point of supply - the junction of the consumers mains with—

- a) conductors of an electricity distribution system; or
- b) output terminals of an electricity generating system within the premises.

Reference – AS/NZS 3000:2007 Clause 1.4.75

What considerations need apply to the unprotected PV array consumers mains (dc array cable)?

The PV (DC) array cable between the arrays and inverter are deemed to be electrically unprotected consumers mains.

Unprotected consumers mains would normally be installed fully enclosed in heavy duty conduit.

As a PV array is a current limited generator the Australian Standards EL 042 committee ruled that the DC cable can be installed with mechanical protection, this can be achieved by the cable location or additional protection by installation within a wiring enclosure.

Consumers mains not provided with short-circuit protection on the supply side, shall—

- a) be constructed in such a manner as to reduce the risk of short-circuit to a minimum; and
- b) be installed in accordance with the relevant additional requirements of the electricity distributor.

The following wiring systems are deemed to reduce the risk of short-circuits to a minimum:

- i. Insulated and sheathed cables enclosed in heavy-duty insulating conduit to AS/NZS 2053.
- ii. Insulated and sheathed cables installed in underground wiring enclosures.

Reference – AS/NZS 3000:2007 Clause 3.9.7.1.2

FAQ 20-2009 - Consumers mains - Unprotected

Under what conditions would an unenclosed, insulated and sheathed cable be permitted as unprotected consumers mains for installations?

Subject to any additional requirements or restrictions of the electricity distributor, the following installation conditions for an insulated and sheathed cable are deemed to minimise the risk of short-circuit:

- a) Installed in areas that would not be subject to mechanical damage (see Clause 3.9.4), for example –
 - i. supported more than 50mm from surfaces in a roof space that may be penetrated by nails, screws or drills and in a location not subject to damage by access within the roof space
 - ii. run in double brick or brick veneer wall cavities; or
 - iii. supported by cable trays or ladders or at the point of attachment at a height of not less than 2.5m from the ground, floor or platform (out of arms reach); and,
- b) Additional mechanical protection of the cable, by insulating, enclosing or installing barriers, at any points along the mains likely to be damaged due to movement, for example where the cable passes through or contacts abrasive building materials or for any other reason.

Additional requirements may be applied by various States in Australia.

Reference – FAQ 020/2009: AS/NZS 3000:2007—CLAUSE 3.9.7.1.2

The section of consumers mains installed between the inverter and the switchboard are considered to be electrically protected when an appropriate sized ac circuit-breaker is installed as the solar main switch.

What type of cable is suitable for the dc PV array wiring system?

To minimise corrosion (*electrolytic effect*) and the risk of breakage the cables should be fine-stranded tinned copper conductors.

The cable shall be rated for the maximum voltage and current carrying capacity to which it is subjected.

PV array cables shall be clearly identified so they cannot be mistaken for other power cables within the installation.

The cross-sectional area of the DC cable shall be a minimum of 4mm² and rated at the appropriate voltage.

Note: Where PV array cabling could be confused with other wiring systems, appropriate identification shall be provided at regular intervals (typically, identification should be not more than 3 m apart).



Cable size - the minimum cable sizes for PV array wiring, based on current carrying capacity, shall be based upon a current rating calculated from Table 3.1 of AS/NZS 5033.

NOTE: When calculating cable size, consideration needs to be given to;

- (a) voltage drop (a maximum of 5% is recommended); and
- (b) de-rating of the current carrying capacity of a cable due to temperature.

Australian Standards EL 42 committee proposed changes.

Standards Australia Committee (EL-42) propose changing the appropriate standards to reflect the following changes;

Due to the inability to provide short-circuit protection at the origin of the circuit, the DC PV Array cable shall be mechanical, protected, this can be achieved by the cable location or installing the cable in PVC conduit complying with AS/NZS 2053. Where the wiring system or conduits are exposed to direct sunlight protection against UV shall be provided.

The DC PV array cable shall be of a type specifically designed for DC currents and comply with the appropriate IEC standards.

Do I need to provide isolation for the PV array (DC) cable at or near the inverter?

Yes - it requires an appropriately rated DC device unless the inverter is physically integral with the energy source.

Isolation of the inverter from the energy source - an isolation device shall be provided between the energy source and the inverter unless the inverter is physically integral with the energy source. This device shall comply with the requirements for devices for isolation and switching in AS/NZS 3000 and be capable of safely breaking voltage and current under both normal and fault conditions.

Reference AS/NZS 4777.1 -2005 Clause 5.4



DC isolation and switching devices – general requirements

All switching devices shall comply with all the following requirements:

- a) Be rated for DC use.
- b) Have a voltage rating equal to, or greater than, $1.2 \times V_{OC \text{ ARRAY}}$.
- c) Not have exposed metallic live parts in the connected or disconnected state.

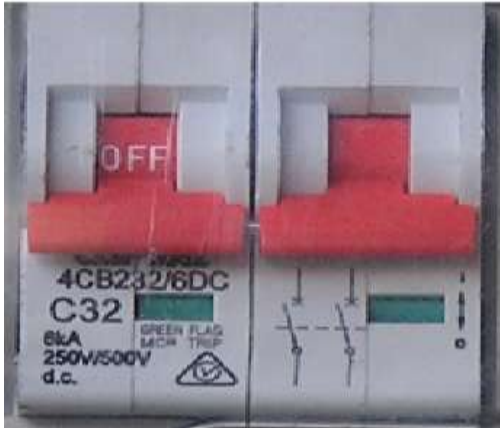
Non-load-breaking switches shall have a current rating equal to, or greater than, their associated fault current protection device, or in the absence of such device, have a current rating equal to, or greater than, the required current carrying capacity of the circuit to which they are fitted.

AS/NZS 5033 Clause 4.3.3 Current breaking devices.

In addition Circuit breakers and any other load breaking disconnection devices used for protection and/or disconnecting means shall comply with all the following requirements:

- a) Not be polarity sensitive (as fault currents in a PV array may flow in the opposite direction to normal operating currents) except for the PV array main switch in systems without batteries.
- b) Be rated to interrupt full load and prospective fault currents from the PV array and any other connected power sources (e.g. batteries, generators and the grid).
- c) When fault current protection is incorporated, the trip current shall be rated according to fault current protection requirements.

The PV Array double-pole isolator specified on the DC side of the inverter is required to be a load breaking isolator, but many installers are using double pole DC circuit-breakers because they are readily available. These DC circuit-breakers can be polarized or non-polarized. It is anticipated that the new version of AS/NZS 5033 will not allow polarized breakers to be used. Additional Information is available from “Correct wiring of double pole DC Circuit-breakers” - published by Global Sustainable Energy Solutions.



It is essential that polarized breakers are wired correctly as they are a potential fire hazard when incorrectly wired.

Do I need to link the DC circuit breakers when there are multiple DC supplies feeding into an inverter?

It is desirable to link the circuit breakers for the isolation of supply, but it's not mandatory. If the circuit breakers are not linked there is a possibility that there is a voltage on the load side of the circuit breaker that is turned off. A sign advising users to isolate all DC supplies is required.

Are all inverters suitably IP rated for outdoor installation?

No. not all inverters are suitable to be installed where they are exposed to weather.

Caution - Inverters with IP rating can be similar in appearance to those without an IP rating. Check the specifications supplied with the inverter



Is there a minimum or maximum height for the installation of an inverter?

Yes -the maximum height to the top of the inverter is 2 metres above ground, floor or platform, the minimum height to the bottom of the inverter shall not be less than 500mm from ground, floor or platform.

Do I need to provide isolation for the AC circuit at or near the inverter?

Yes - a device that provides isolation is required to be mounted immediately adjacent to the inverter.

Exception: the above device is not required to be installed if the inverter is mounted within direct view and within 3 metres from the switchboard.

Where the inverter is not in close proximity to the switchboard it supplies, some form of overcurrent protection shall be provided to prevent excessive current flow through the cables feeding into the switchboard unless the inverter is supplied from a current limited source.

NOTES:

1. Typically cable lengths of 3 m would be considered as close proximity (*close proximity means within 3 metres and within direct view of the switchboard*).
2. A solar (PV) array is a current limited source.
3. The preferred location for this overcurrent protection device is at the inverter end of the cable.
Reference AS/NZS 4777.1:2005 Clause 5.3.5 &5.4

How should I connect the inverter energy system (generator) to the installation?

The inverter energy system shall be connected by fixed wiring to a dedicated circuit on a switchboard.

The inverter energy system should be connected directly to the main switchboard.

In installations where this is not possible or not desirable, the inverter energy system should be connected to the distribution board located physically nearest the inverter, and the main switchboard.

All intermediate distribution boards shall be appropriately labelled in accordance with Clause 5.5 of AS/NZS 4777.1.

Reference AS/NZS 4777.1 -2005 Clause 5.3.1

All the cables between the inverter energy system and any switchboard and all the cables between any distribution boards and a main switchboard which carry current from the inverter energy system shall be rated for at least the full output current of the inverter energy system and, if the inverter energy system is configured as a UPS, for at least the full input current of the inverter energy system.

Reference AS/NZS 4777.1 -2005 Clause 5.3.2

Does the solar main switch need locking facilities?

Yes - the main switch shall be provided with a permanent locking facility so it can be the locked in the off position. This cannot be achieved using a plug in circuit breaker in a semi enclosed rewirable fuse base.

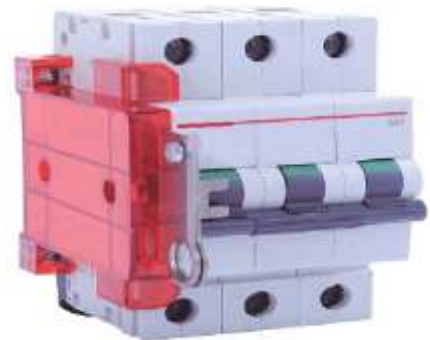
The solar main switch for the switchboard, to which the inverter energy system is connected, shall be a lockable switch.

An appropriately labelled lockable isolation switch or circuit breaker, which is lockable in the OFF position and operates in all active conductors, shall be provided on the switchboard to which the inverter energy system is directly connected.

This switch shall be capable of breaking the full output current of the inverter. Operation of this switch shall isolate the inverter energy system from that switchboard. This isolation switch shall be installed to the requirements for main switches, as specified in AS/NZS 3000.

NOTE: This switch is to provide isolation of the inverter energy system for persons working on other parts of the electrical installation.

Reference AS/NZS 4777.1 -2005 Clause 5.3.3



Common requirements for isolating devices

Provision shall be made to enable isolation of electrical equipment and to prevent electrical equipment from being inadvertently energized. The means of isolation shall be such that a deliberate action in addition to the normal method of operation is required to energize the circuit.

NOTE: Such precautions may include one or more of the following measures:

- a) Provision for the fitting of a padlock.
- b) Location within a lockable space or enclosure.

What are the signage requirements?

The purpose is to clearly indicate that the installation has multiple supplies and to indicate which circuits are affected by these supplies.



This sign shall be placed on the switchboard where the solar energy system is connected.

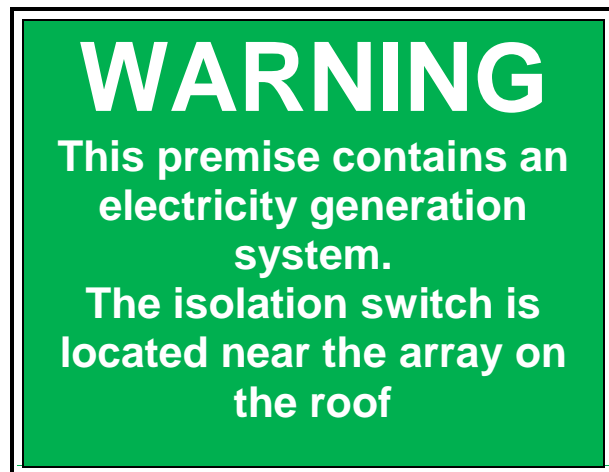
If the solar energy system is connected to a sub-board signs shall also be placed on the main switchboard and all intermediate switchboards.

Reference AS/NZS 4777.1 -2005 Clause 5.3.1

If the system is installed within a multiple installation these labels should be placed on the switchboard of the installation containing the solar system and on the distribution boards that supply that occupancy.

This sign shall be placed at the main switchboard and any fire indicator panel.

It must also indicate the LOCATION OF ISOLATION SWITCHES FOR EACH GENERATION SYSTEM.



The main switch should be identified in accordance with Clause 2.3.3.4 (a) of AS/NZS 3000:2007, and all main switches in the installation must be identified in accordance with Clause 2.3.3.4 (b).

Reference: The Electricity Safety (Installations) Regulations 2009 Reg. 210.

Reference: AS/NZS3000:2007 Clause 2.3.3.4

Reference: AS/NZS4777.1:2005 Clause 5.5

In addition, the Service and Installation Rules require marking on the meter panel where the meters are remote from the switchboard, and on the mains in the pit for underground supplies, or at the Point of Attachment, on or adjacent to the FOLCB for overhead supplies.



Reference – Victorian Distributors Service & Installation Rules

Can I use the solar generation system before it's inspected?

No - all prescribed electrical installation work must be inspected by licensed electrical inspector within 8 business day after the completion of the work.

Electricity distributors require that the solar system remains disconnected until the correct metering is installed and associated test are carried out by the distributor representative.





Reference – Victorian Distributors Service & Installation Rules

What Information is required on the Certificate of Electrical Safety?

The Certificate of Electrical Safety should state:

- The location of the PV Array, and the number of modules in the PV array, including number of strings if relevant;
- The rating of the PV array;
- The Voc and Isc of the array;
- The location of the inverter if it is not obvious;
- The type of inverter (eg non-isolated, transformer-less etc) unless this information is readily available on the inverter nameplate. (See next page)

	Type
	Art.No.

  Q041167		UAC nom.	230V / 50 Hz
		IAC nom.	5,7 A
		P nom.	1300 W
		cos φ	1
		UDC MPP	150 - 400 V
		UDC max (-10 °C, 1000W/m²)	500 V
		IDC max	10,3 A

IP 45

EN 50178/EN 61000-6-2/EN 61000-6-3/EN 61000-3-2

Optionen
Outdoor standard with display
SETUP AUS
1DC-plug outdoor

What part of the solar PV Array does an Electrical inspector need to Inspect?

Section 8 of AS/NZS 3000:2007 presents the minimum requirement of inspection and testing, it is expected the following items shall be additional to satisfy the minimum safety principles of Part 1 of AS/NZS 3000:2007 and the Electricity Safety (Installations) Regulations 2009.

The inspection shall include but is not limited to the following:

- The PV Array wiring for fixing and mechanical protection and isolation requirements.
- The Array frame and supports for protective earthing or equipotential bonding where required.
- PV Array isolating device for DC voltage and current rating, correct connection, location, UV protection and IP rating.
- The DC cable for compliance to the standard, mechanical protection, UV protection, correct polarity, size, voltage rating, roof penetration, labelling where required and voltage drop.
- The DC isolator for the proximity to the inverter, current rating, UV protection, correct connection, location and IP rating.
- The inverter for fixing, height requirements, earthing, correct connections, IP rating, UV protection and operation.
- The AC circuit breaker near the inverter if installed.
- The AC circuit wiring for polarity, current rating, mechanical protection.
- The switchboard to which the solar supply is connected for circuit arrangement, main switch rating, and marking.
- Ensure that there is no RCD installed between the inverter and point of supply.
- Ensure the solar neutral is identified as required.
- The meter panel, pit or FOLCB for marking.
- The installation of signage if the solar supply is connected to a sub-board.
- The installation of signage specifying the Voc and short-circuit currents is displayed on the main switchboard or at the sub-board if the solar supply is connected to a sub-board.
- The installation of signage if the solar supply is connected within a multiple installation.



We would like to thank all those who contributed to the development of this document.