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INSTALLATION REQUIREMENTS

INSTALLATION AND INSPECTION OF GRID-CONNECTED PV SYSTEMS APRIL 2015 (NO BATTERY STORAGE)

This document has been prepared by Energy Safe Victoria (ESV) 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 Distributor's Service and Installation rules. 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:

- Electricity Safety Act 1998
- Electricity Safety (Installations) Regulations 2009
- Victorian Distributors Service and Installation Rules 2014
- AS/NZS 3000:2007 – Wiring Rules including amendments
- 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
- AS/NZS 5033:2014 – Installation of photovoltaic (PV) arrays

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 a single component of an electrical installation by an equivalent component part in the same location, such as an inverter or isolator switch, can be entered on a non-prescribed certificate without the mandatory inspection.

NOTE: Equivalent component part in the case of the inverter means:

> **"the same brand and model" – however, if the same model is no longer available the model the supplier deems to be an equivalent**
>
> **Being: same AC output power or less and compatible input voltage range**
> *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 50V AC or 120V ripple-free DC
>
> **Low Voltage**: Exceeding extra-low voltage, but not exceeding 1000V AC or 1500V 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 3000 Clause 1.4.2.8 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.

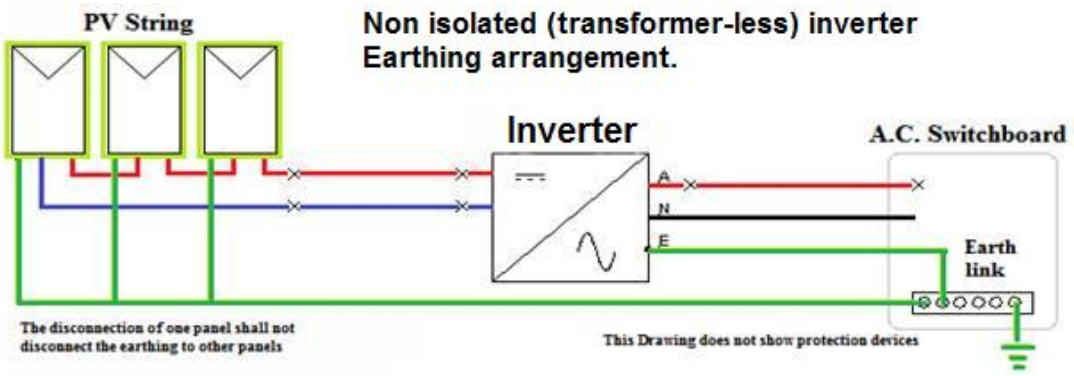
Protection by electrical separation shall be afforded by compliance with Clauses 7.4.2 to 7.4.4, of AS/NZS 3000:2007 and with –

(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

ARE THE EXPOSED METALLIC PARTS OF THE SOLAR ARRAY REQUIRED TO BE EARTHED OR EQUIPOTENTIAL BONDED?

In PV arrays with a PV array maximum voltage greater than ELV and in systems which include AC modules and microinverters with LV outputs, all exposed metal PV module frames shall be earthed and the array mounting frames shall also be earthed. Earthing/bonding of exposed conductive parts of a PV array shall be performed in accordance with Figure 4.5 decision tree.



The earthing requirements of other solar generation systems shall be determined by following figure 4.5 of AS/NZS 5033:2014 'PV array framework earthing decision tree.'

The purpose of earthing/bonding PV module frames is both for protective and functional reasons. The functional aspect of this requirement enables the PCE's earth fault detection to detect leakage to earth and provide alarm indication. The requirement of a minimum size of 4 mm2 applies to the frame earth connections and is for mechanical durability reasons.
Reference - AS/NZS 5033:2014 Clause 4.4.2.2 - Note

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 $4mm^2$.
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 $4mm^2$.
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 and AS/NZS 5033:2014.
Reference –Clause 3.2 of AS/NZS 5033:2014

Clauses related to the wiring connecting panels and arrays:

Wiring Loops - Installation
Reference - Clause 3.5.2(b) and 4.4.4.4 of AS/NZS 5033:2014

String Wiring - Installation
Reference – Clause 4.4.4.5 of AS/NZS 5033:2014

IP Rating of the Enclosure and Cable Entries
Reference – Clause 4.4.4.6(b) of AS/NZS 5033:2014

Location of PV Array and PV String Combiner Boxes
PV array and PV string combiner boxes, where installed, shall be readily available
Reference – Clause 4.3.3.2 of AS/NZS 5033:2014

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;
- Shall not be capable of being overridden or bypassed by programmable control systems or the like; and,
- Meet the requirements of Clause 4.3.5 of AS/NZS 5033:2014

Disconnecting means shall be provided in PV arrays according to Table 4.3 of AS/NZS 5033:2014, to isolate the PV array from the PCE or application circuit and vice versa, and to allow for maintenance and inspection tasks to be carried out safely.

Except for AC module inverters, it shall be possible to isolate the PCE from all poles of the array such that maintenance of the PCE is possible without risk of electrical hazards.

ARE THE CONDUCTORS INSTALLED BETWEEN THE PV ARRAY AND THE MAIN SWITCHBOARD CLASSIFIED AS CONSUMER'S MAINS?

No – However they must be protected as detailed in AS/NZS 5033:2014 Clause 4.3.6.3.

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.

Cables used within the PV array shall:

(a) Have a temperature rating according to the application;
(b) If exposed to the environment, be UV-resistant, or be protected from UV light by appropriate protection, or be installed in UV-resistant conduit (refer to IEC 61386-1); and,
(c) Be flexible (multistranded) to allow for thermal/wind movement of arrays/PV modules.

LV string cables in all systems and all LV DC cables installed in domestic systems shall comply with:

i. PV1-F requirements;
ii. UL 4703; or,
iii. VDE-AR-E 2283-4.

In all systems, cables shall be selected so as to minimize the risk of earth faults and short-circuits.

NOTES:

1. For systems with LV cables, this is achieved using double-insulated cables, particularly for cables that are exposed or laid in metallic tray or conduit. This can be achieved by double insulated wiring as shown in Figure 4.2 and with extra mechanical protection where required.
2. Attention should be given to the issues of eddy currents when running conductors in metal conduit or trunking.
3. PV1-F cable requirements may be found in the document TUV 2 PfG 1169/08.2007.
4. TPS cables complying with AS/NZS 5000 series are not suitable for this application.
5. For LV systems, tinned copper is recommended to reduce degradation of the cable over time PV modules frequently operate at temperatures in the order of 40°C above ambient temperature. Cable insulation of wiring installed in contact with or near PV modules shall be rated accordingly.

PV array cables shall be clearly identified so they cannot be mistaken for other power cables within the installation and marked at a maximum distance of 2 meters.

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 4.2 of AS/NZS 5033:2014.

DO I NEED TO PROVIDE ISOLATION FOR THE PV ARRAY (DC) CABLE AT OR NEAR THE INVERTER?

Yes - It requires an appropriately rated DC disconnection 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

Disconnecting means shall be provided in PV arrays according to Table 4.3 of AS/NZS 5033:2014 to isolate the PV array from the PCE or application circuit and vice versa, and to allow for maintenance and inspection tasks to be carried out safely.

The disconnecting means for PCEs shall meet the requirements for switch-disconnectors as set out in this Clause 4.4.1, except in the case of AC modules or small micro inverter installations that comply with Clause 4.3.12.

Except for AC module inverters, it shall be possible to isolate the PCE from all poles of the array such that maintenance of the PCE is possible without risk of electrical hazards.

Connectors complying with Clause 4.3.7 may be used between PV modules and small micro inverters complying with Clause 4.3.12, provided there is a warning attached to the connector prohibiting disconnection of the PV module and the inverter under load.

For all other PCEs repaired by replacement, one of the two following disconnecting methods shall be used:

a) An adjacent and physically separate switch-disconnector; and,
b) A switch-disconnector that is mechanically interlocked with a replaceable module of the PCE, and allows the module to be removed from the section containing the switch-disconnector without risk of electrical hazards.

In restricted access installations PCEs may be repaired by replacing internal components.

In this situation, the switch-disconnector shall be located such that maintenance of the PCE (e.g. change of an inverter module, change of fans, cleaning of filters) is possible without risk of electrical hazards. This switch-disconnector may be in the same enclosure with the PCE.

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 an 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 in 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 in 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 and 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

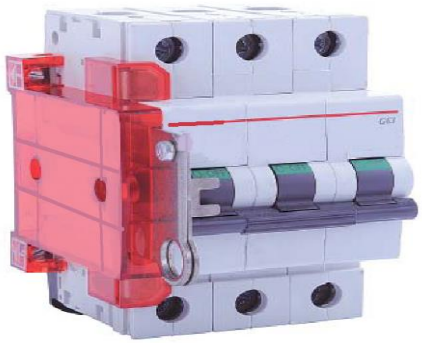
DOES THE SOLAR MAIN SWITCH NEED LOCKING FACILITIES?

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 re-wirable 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 3000:2007.



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

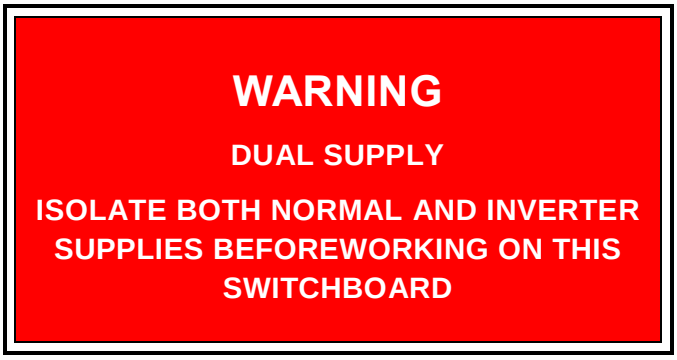
Provision shall be made to enable isolation of electrical equipment and to prevent electrical equipment from being inadvertently energized. The means of isolation shall be such that a deliberate action in addition to the normal method of operation is required to energize the circuit.

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.

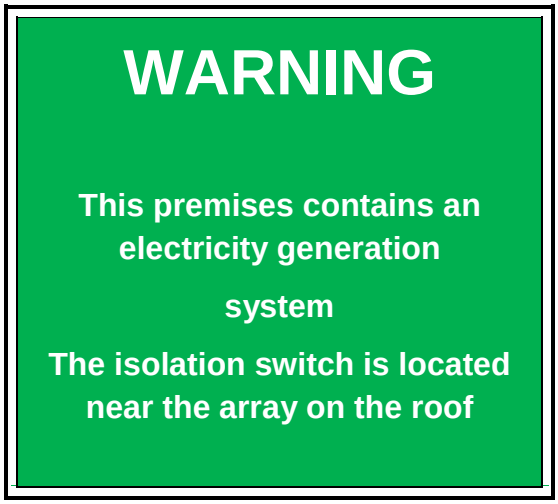
If the solar energy system is connected to a sub-board signs shall also be placed on the main switchboard and all intermediate switchboards.

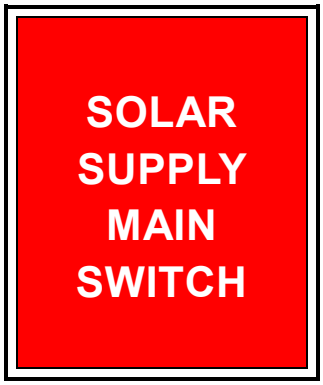
Reference AS/NZS 4777.1:2005 Clause 5.3.1

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.

WARNING

DUAL SUPPLY
ISOLATE INVERTER SUPPLY AT MAIN SWITCHBOARD

Reference – Victorian Distributors Service & Installation Rules

Refer to Section 5 of AS/NZS 5033:2014 for full details.

CAN I USE THE SOLAR GENERATION SYSTEM BEFORE IT'S INSPECTED?

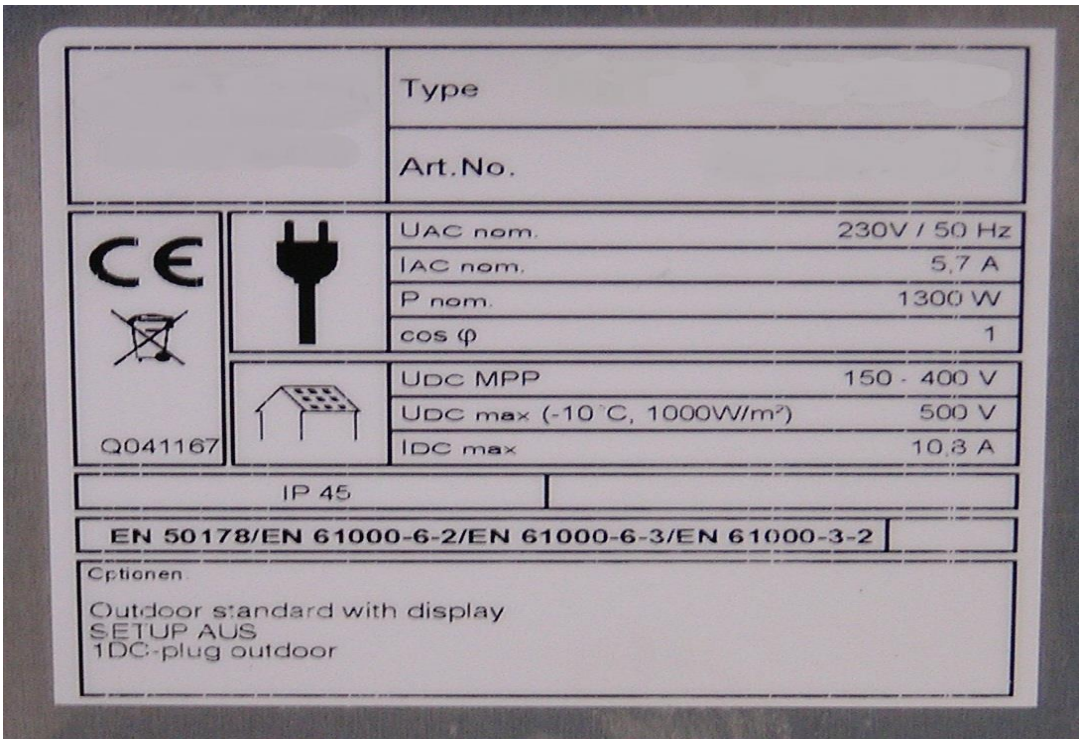
No - All prescribed electrical installation work must be inspected by a licensed electrical inspector within 8 business days after the completion of the work.

Electricity distributors require that the solar system remains disconnected until the correct metering is installed and associated tests 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 (e.g. non-isolated, transformer-less etc.) unless this information is readily available on the inverter nameplate.



WHAT PART OF THE SOLAR PV ARRAY DOES AN ELECTRICAL INSPECTOR NEED TO INSPECT?

Section 8 of AS/NZS 3000:2007 present tested in the minimum requirement of inspection and testing, it is expected the following items shall tested in be addition 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 fixing, 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; and,
- The installation of signage if the solar supply is connected within a multiple installation.