Clean Energy Council

GRID-CONNECTED PV SYSTEMS (No Battery Storage)
SYSTEM INSTALLATION GUIDELINES
for Accredited Installers and Supervisors

Clean Energy Council ACCREDITED

GENERAL

The performance of a reliable installation that fulfils a customer's expectations requires both careful design and correct installation practice. Compliance with relevant State Health and Safety regulations is necessary.

STANDARDS for INSTALLATION

The main standards required are …

AS/NZS 3000 Wiring Rules
AS/NZS5033 Installation of Photovoltaic (PV) Arrays
AS 4509 Stand-alone Power Systems
AS 1170.2 part 2: Wind Loads
AS 4777.1 Grid connect - Installation
AS 1768 Lightning Protection
AS/NZS 3008 Selection of cables

The grid-interactive inverter shall be tested in accordance with the AS 4777 parts 2 and 3 and the system shall comply with the relevant electrical service and installation rules for the state where the system is installed.

DOCUMENTATION

All complex systems require a user manual for the customer. Grid-connected PV systems are no different. The documentation for system installation that should be provided is …

- List of equipment supplied.
- Shutdown and isolation procedure for emergency and maintenance.
- Maintenance procedure and timetable.
- Commissioning sheet and installation checklist.
- Warranty information.
- System connection diagram.
- Equipment manufacturers documentation and
- Handbooks for all equipment supplied.

RESPONSIBILITIES OF ACCREDITED PERSON WHEN COMPLETING SYSTEM

As an accredited person, when signing off on a system you have either

1. ***Undertaken the installation yourself***

or

2. ***Supervised the installation by others.***

Supervision includes:

* *Visiting the site while the installation is occurring*
* *Testing & commissioning the system and completing the commissioning sheets. (part of these guidelines)*

These guidelines have been developed by Clean Energy Council. They represent latest industry BEST PRACTICE for the design and installation of PV Grid Connected Systems.

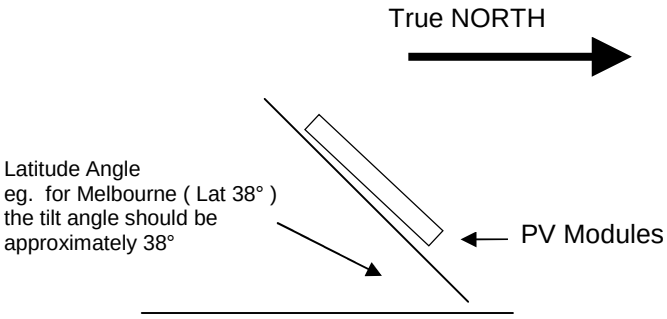
PV ARRAY

ORIENTATION AND TILT

In grid connected PV systems the solar array is generally mounted:

- "Flat" on the roof OR
- Integrated into the building OR
- On an array frame that is tilted to fix the array at a preferred angle (usually for flat roofs).

For best year-round performance a fixed PV array should be mounted facing true north (± 5°) at an inclination equal to the latitude angle.



If the array is "flat" on the roof or integrated into the building fabric, the array will often not be at the preferred (optimum) tilt angle and in many situations will not be facing due north.

Included with the design guide is a set of tables for the following locations:

- Hobart
- Melbourne
- Canberra
- Sydney
- Brisbane
- Cairns
- Adelaide
- Alice Springs
- Darwin
- Perth

These tables show the average annual daily total irradiation represented as a percentage of the maximum value

i.e. PV orientation is true North (azimuth = 0°) with an inclination equal to the latitude angle.

They provide values for a plane in 36 orientations (azimuths) and 10 inclination (tilt) angles. [increments of 10^{o}] and have been derived from the Australian Radiation Data Handbook (Table 5.13)

The tables provide the system designer/installer with information on the expected output of a system (with respect to the maximum possible output) when it is located on a roof that is not facing the true north (± 5°) at an inclination equal to the latitude angle.

ROOF MOUNTING [not building integrated]

- If the modules use crystalline cells then it is preferable to allow sufficient space below the array (> 50mm) for ventilation cooling. This will be subject to the constraints of the customer or architect.
- All supports, brackets, screws and other metal parts should be of similar material or stainless steel to minimise corrosion.
- Where timber is used it must be suitable for long-term external use and fixed so that trapped moisture cannot cause corrosion of the roof and/or rotting of the timber.
- Any roof penetrations must be sealed and waterproof.
- All fixings must ensure structural security when subject to the highest wind speeds for the region and local terrain - refer to AS1170.2 This may require specific tests of the fixing/substrate combination on that roof.
- All external wiring must be protected from UV and mechanical damage.

FREE STANDING PV ARRAYS

Must be wind rated in accordance with AS 1170.2 part 2: Wind Loads.

BUILDING INTEGRATED (BIPV) INSTALLATIONS

The installation of modules that are being used as building material eg. tiles, building walls, sun-screens should only be installed by a person qualified to install that particular type of building element.

INVERTER INSTALLATION

If the inverter is designed to be installed behind the module (AC module) then consideration should be given to adequate ventilation to avoid excessive loss of capacity through high temperature, and to the ease of replacement in the event of an inverter failure. In many cases, where the inverter is not provided physically mounted on the module, then it is preferable to group such 'micro' inverters in a centralised enclosure or panel off the roof.

If a central inverter (or inverters) is used and the inverter enclosure is not weatherproof (eg. IP 56 rated) then these should either be located inside the building or in an appropriate weatherproof enclosure. The enclosure should provide adequate internal space and external ventilation to facilitate cooling of the inverter.

EQUIPMENT PROTECTION AND ISOLATION

AS4777 states all the requirements for protection and isolation when connecting inverters with the grid and all systems shall be installed in accordance with that standard.
AS5033 states all the requirements for protection and isolation within the PV array and all systems shall be installed in accordance with that standard.

Note - The system shall be installed in accordance with all relevant electrical service and installation rules for the state where the system is installed

CABLE SELECTION

For extra low voltage (ELV) arrays and low voltage (LV) arrays …

- All cabling must be sized in accordance with AS/NZS 3000 and AS/NZS 3008.
- Cable losses between the PV array and the inverter should never exceed 5% to maximise system output power. Particularly with larger systems, this loss should be kept as small as possible.

CABLE PROTECTION

The cables shall be electrically protected in accordance with AS/NZS 3000 and AS/NZS 3008.

All cables used in the installation should be securely fixed in place to minimise any movement of the cable in accordance with AS3000.

Mechanical protection of the cables shall be in accordance with AS/NZS 3000.

WIRING OF LV ARRAYS

The electrical installation of the array shall be in accordance with AS/NZS5033:2005 Installation of PV Arrays.

It is suggested that the array, if possible, be covered (during cabling) to reduce the voltage and current being generated by the PV modules.

A dangerous situation occurs when the person installing the system is able to come in contact with the positive and negative outputs of the solar array string when the output voltage is 120V DC or above.

Many grid-connected systems have solar modules which are supplied with plugs.

The method outlined in this procedure is to be followed if the interconnection between the solar modules will be hard wired. It has been written to prevent a person being able to touch the two live array LV output cables either within :

- a module junction box OR
- the isolating switch located near the array.

Using this method, the junction boxes on the modules will only have a live (nominal) ELV supply of 12V or 24V maximum.

Please read this procedure while studying figure 1.

a) The positive cable from the isolating switch or breaker is connected to the solar module junction box which is designated as the positive connection. This cable is double-insulated and there are no other electrical connections between the isolating switch and the array positive junction box.

b) The negative cable from the isolating switch or breaker is connected to the solar module junction box which is designated as the negative connection. This cable is double-insulated and there are no other electrical connections between the isolating switch and the array positive junction box.

c) To ensure that the installer does not work on live positive and negative cables in close proximity within the isolation switch:

either the positive and negative cables are electrically connected to the double pole isolating switch or breaker prior to electrically terminating the cables within the array junction boxes

and/or there is a 'multi-contact' style insulated plug and socket connection in the middle of the array which is connected after the array is wired and the cables are connected in the isolation switch.

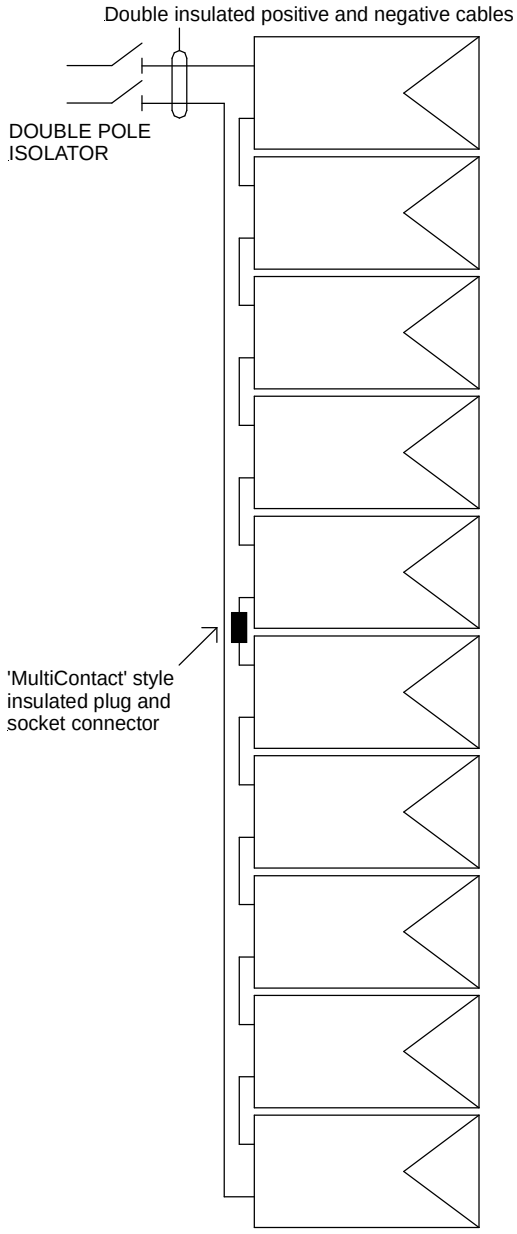


Figure 1 PV string connection

METERING

The PV grid-connected system should be interconnected to the grid at a switchboard or distribution board as required by the local electricity distributor's guidelines.

The metering that will be installed will vary in accordance with the local electricity distributor's guidelines. Some inverters have on-board metering of the instantaneous and cumulative output of the PV system. Where this is not the case and the distributor's approved metering does not provide a recording of the output of the PV inverter system, it is recommended that a separate meter is installed to ensure that the output of the PV inverter system is recorded.

SIGNAGE

All signage on switches, isolators and within distribution boards and switchboards shall be in accordance with AS 4777 and AS/NZS5033 and/or the relevant electrical service and installation rules for the state where the system is installed.

LV PV array cable shall be clearly identified as DC LV cable to ensure that it is not mistaken for AC cable.

COMMISSIONING

The commissioning sheets provided with these guidelines shall be completed by the accredited installer or the accredited supervisor (with suitable licensed person) . A copy shall be provided to the customer in the system documentation and a copy retained by the accredited person.

LICENSING

EXTRA LOW VOLTAGE (ELV)

All extra low voltage wiring should be performed by a 'competent' person, which is defined by the Australian Standard - 4509.2 Stand-alone Power Systems as …

" a person who has acquired through training, qualifications, experience or a combination of these, knowledge and skill enabling that person to correctly perform the task required."

LOW VOLTAGE (LV)

All low voltage work (240V) must be performed by a licensed electrician.
A licensed electrician is required to be responsible for the safety of the system wiring prior to connection of the system to the grid.
If the system contains ELV wiring installed by a non-licensed person, then a minimum level of checking by the electrician prior to closing the PV array isolators would include:

- An open circuit voltage test on each PV string and on the total array
- A visual inspection of an open PV junction box (randomly selected) and the master array junction box.

These inspections/checking shall confirm:

- The array voltages are as designed and specified
- The appropriate cables (CSA and insulation), junction fittings and enclosures have been used.

An accredited non-electrician ELV installer would be expected to have also carried out these checks.

These guidelines alone do not constitute a fully definitive set of rules and are to be read in conjunction with all relevant Australian Standards

INSTALLATION CHECKLIST

PV ARRAY

Mounted flat on roof ☐
Building integrated ☐
Mounted on tilted array frame ☐
PV Array tilt ……°
PV Array orientation ……°
Solar array is securely fixed ☐

Details……

Timber used is suitable for external use or is properly sealed ☐
No dissimilar metals are in contact with the array frames or supports ☐
Roof penetrations are suitably sealed and weatherproofed ☐
PV wiring losses are less than 5% at the maximum current output of the array ☐
Weatherproof isolator is mounted immediately adjacent to the array ☐
Wiring is protected from UV and mechanical damage ☐

INVERTER

Double pole DC isolator (or DC circuit breaker mounted close to input of the inverter (Rating. ……A) ☐
Isolator mounted on output of the inverter (can be part of inverter) ☐
AC circuit breaker mounted within the switchboard to act as main switch for the PV / inverter system. (Rating …….. A) ☐
Inverter is housed in weatherproof enclosure or inside building ☐
Adequate space and ventilation for inverter ☐

LV DC CABLING

Is clearly identified in accordance with these guidelines ☐

SIGNAGE (White on Red) AS 4777.1 and Appendix A

WARNING
Dual Supply
Isolate Both Normal and Solar Supplies before working on this

is permanently fixed on the switchboard. ☐

Normal Supply MAIN SWITCH — is permanently fixed to main switch ☐

Solar Supply MAIN SWITCH — is fixed on main solar switch ☐

If the solar system is connected to a distribution board then the following sign is located on main switchboard and all intermediate distribution boards

WARNING
DUAL SUPPLY
ISOLATE SOLAR SUPPLY AT DISTRIBUTION BOARD DB???

☐

Where the inverter is not adjacent to the main switchboard, location information is provided ☐

Warning and Advisory Signs AS/NZS5033 Appendix G

SOLAR DC — is permanently fixed on array junction boxes (Black on White) ☐

SOLAR ARRAY
ON ROOF

Open circuit voltage: 220 V
Short circuit current: 20 A

Colour: White on red

Fire Emergency information is permanently fixed on the main switchboard ☐
(White on Red)

Shutdown procedure is permanently fixed at inverter and/or on main switchboard ☐

230-240 VOLT (LV) INSTALLATION

All low voltage wiring has been installed by a licensed electrical tradesperson ☐
All wiring has been tested and approved by a qualified electrical tradesperson ☐

This checklist is based on the Clean Energy Council's GC Design and Installation Guidelines. The Guidelines demonstrate the latest industry "best practice" and are to be read in conjunction with the relevant Australian Standards.

AUTHORISATION : I, ……

CEC Accreditation number …… verify that the following system has been installed to the standard indicated by these guidelines and complies with all applicable Australian Standards

Name of the person for whom the system was installed ……..

Location of system ……..

signed …….. Date : / / *Attach a separate sheet detailing any departures*

TESTING and COMMISSIONING

PV ARRAY- DC

NOTE : where there is only 1 string and no array junction box, then the following tests will be conducted between the strings and the d.c main switch at the inverter.

Isolate PV string and array wiring

CHECK that there is no voltage on input ☐
OR output sides of any array junction box (where installed)

CHECK
Continuity between strings and array junction box

- String 1 +ve ☐
- String 1 -ve ☐
- String 2 +ve ☐
- String 2 -ve ☐
- String 3 +ve ☐
- String 3 -ve ☐
- String 4 +ve ☐
- String 4 -ve ☐

Continuity between
array junction box and PV DC main switch ☐

CHECK
Polarity of PV string and array wiring

- String 1 ☐
- String 2 ☐
- String 3 ☐
- String 4 ☐
- Array +ve ☐
- Array -ve ☐

Polarity of wiring between
array junction box and PV DC main switch ☐

WARNING:
IF POLARITY OF ONE STRING IS REVERSED, THIS CAN CAUSE A FIRE IN THE ARRAY JUNCTION BOX.

RECORD PV string open circuit Voltage

String 1 V
String 2 V
String 3 V
String 4 V

WARNING:
The following procedures describe how to measure short circuit currents - the voltages can be very high and if the procedures are not followed then arcing and damage to components could occur.

Note : Some projects require that short circuit currents are recorded as part of the contractual commissioning, otherwise a record of the actual operating current of each string is sufficient.
This could be done by using the meter on the inverter or by using a clamp meter when the system is operational.

Where short circuit currents are required then to do the following tests safely:

1. Ensure each string fuse (where required) is not connected or that LV array is still broken into ELV segments
2. Leave solar array cable connected to the main solar DC switch.
3. Remove the cable from the DC main switch to the inverter.
4. With the DC switch off- put a link or small cable between the positive and negative outputs of the DC main switch.
5. Install the string fuse for string 1 or connect the ELV segments to complete the wiring of the string. Turn on DC main switch - using a DC clamp meter measure the DC short circuit current for String 1. Turn off DC main switch. Disconnect string fuse for string 1 or remove links to break string into ELV segments..
6. Repeat point 5 for each string
7. After each string has been individually measured – ensure DC main switch is off- then install all string fuses or connect the ELV segments of each string. Turn on DC switch and measure DC Array current using clamp meter. Turn off switch and remove link in output of DC main switch.

Where short circuit currents are **not** required then record the operating current/s after Start-Up of System.

RECORD
Short circuit Currents (where required) String 1 .....A
String 2 ..... A
String 3 ..... A
String 4 .....A
Array ..... A

With the PV DC main switch **OFF**

CHECK
Continuity between PV DC. main switch and inverter
Array +ve ☐
Array -ve ☐

CHECK polarity between
the PV d.c. main switch and inverter ☐

RECORD
Open circuit voltage at input side
of the array DC main switch V

WARNING: If polarity is reversed at the inverter damage may occur which is generally not covered under warranty

INVERTER – AC

Ensure that the AC grid supply is isolated and
the Solar AC main switch is OFF

CHECK
Continuity between Inverter & Solar AC main switch
Line ☐
Neutral ☐

CHECK
Continuity between Solar AC main switch & kWh meter
Line ☐
Neutral ☐

CHECK polarity at the Inverter
and the Solar AC main switch ☐

CHECK polarity at the output
of Solar AC main switch from the kWh meter ☐

RECORD the voltage at the output
of the Solar AC main switch V

Initial reading of kWh meter .....

Start-Up of System

Refer to system manual for the inverter and follow start-up procedure.

This generally involves turning on the PV DC main switch followed by the Solar AC main switch but the procedures as recommended by the inverter manufacturer must be followed.

System connects to grid [after 60 seconds] ☐
When the AC main switch is turned ON
- follow the inverter start-up procedure -

Voltage at d.c. input of inverter V

Voltage is within operating limits of inverter ☐

Voltage at a.c. output of inverter V

Input power of the inverter (where available) .....W

Output power of the inverter (where available) .....W

Output power as expected ☐

Turn AC main switch OFF
System immediately disconnects from grid ☐

PV Operating current

1. Where there's only one string in the array record the operating current after Start-Up of System.
2. If more than one string - turn off the inverter, the a.c. main switch and d.c main switch. Isolate all strings.
3. With one string connected at a time turn system back on and record the operating current of that string.

Repeat 2 and 3 above
until all string currents have been recorded

NOTE: Any string current tests should be performed on a bright sunny day with no cloud. This is to avoid varied readings due to cloud cover.

RECORD
Operating Currents : String 1 .....A
String 2 ..... A
String 3 ..... A
String 4 .....A
Array ..... A