Clean Energy Council
ACCREDITED

GRID-CONNECTED SOLAR PV SYSTEMS

NO BATTERY STORAGE

Design Guidelines for Accredited Installers

December 2012
(**Effective 1 February 2013)**

These guidelines have been developed by Clean Energy Council. They represent latest industry best practice for the design and installation of grid-connected PV systems.

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1 General

These objectives of these guidelines are to:

- improve the safety, performance and reliability of solar photovoltaic power systems installed in the field
- encourage industry best practice for all design and installation work involving solar photovoltaic power systems
- provide a network of competent solar photovoltaic power systems designers and installers
- to increase the uptake of solar photovoltaic power systems , by giving customers increased confidence in the design and installation work.

The performance of a reliable installation that fulfils customer expectations requires both careful design and correct installation practice. Compliance with relevant state health and safety regulations is also necessary.

NOTE: These guidelines alone do not constitute a fully definitive set of rules and are to be read in conjunction with all relevant Australian standards. Where these guidelines have additional requirements above that stated in the Australian standards then these guidelines should be followed.

2 Definitions

This document uses the same terminology as outlined in AS/NZS 5033. Two important definitions are:

2.1.1 Where the word “shall” is used, this indicates that a statement is mandatory.

2.1.2 Where the word “should” is used, this indicates that a statement is a recommendation.

3 Design and installation standards

Accredited designers shall comply with the following standards where applicable:

AS/NZS 3000	Wiring Rules	AS 4777.1	Grid connect - Installation
AS/NZS5033	Installation of Photovoltaic (PV) Arrays	AS/NZS 1768	Lightning Protection
AS/NZS 4509.2	Stand-alone Power Systems - Design	AS/NZS 3008	Selection of cables
AS 1170.2	Wind Loads		

3.1.1 The grid-interactive inverter shall be tested in accordance with the AS 4777 (parts 2 and 3) and listed on the Clean Energy Council's approved inverter list.

3.1.2 The system shall comply with the relevant electrical service and installation rules for the state where the system is installed. *(NOTE: the local electricity distributor may have additional requirements.)*

3.1.3 These guidelines set additional requirements to the standards. An accredited installer or supervisor is expected to follow these guidelines in addition to the requirements within the relevant standards.

3.1.4 These guidelines will become mandatory on 1 February 2013.

4 Licensing

4.1 Extra Low Voltage (ELV)

4.1.1 All extra low voltage wiring should be performed by a 'competent' person, which is defined by the Australian Standard AS/NZS 4509.1 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."

4.2 Low Voltage (LV)

4.2.1 All low voltage work: >120V DC or >50V AC shall be performed by a licensed electrician.

4.2.2 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 inspection 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 is required to complete a job.

These inspections/checks 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 is expected to carry out these checks.

5 Documentation

The designer is required to provide the following documentation to the installer:

- a list of equipment supplied
- a list of actions to be taken in the event of an earth fault alarm
- the shutdown and isolation procedure for emergency and maintenance
- a basic connection diagram that includes the electrical ratings of the PV array, and the ratings of all overcurrent devices and switches as installed.
- site-specific system performance estimate
- recommended maintenance for the system
- maintenance procedure and timetables.

6 Responsibilities of system designers

System designers must comply with the following responsibilities.

- Provide full specifications of the system including quantity, make and model number of the solar modules and inverter.
- Provide a site specific full system design including all shading issues, orientation and tilt, along with the system's site-specific energy yield, including average daily performance estimate in kWh for each month of solar generation.
- Ensure array design will fit on available roof space.

- Ensure array mounting frame installation will comply with AS1170.2.
- Ensure array configuration is compatible with the inverter specification.
- Ensure all equipment is fit for purpose and correctly rated.
- Obtain warranty information on all equipment.
- When designing a grid connect battery backup system the design shall be performed by a person(s) with CEC grid connected design accreditation and CEC stand-alone design accreditation.

7 Site-Specific Information

To design a system the following site-specific information is required as a minimum:

- occupational safety risks of the site (scaffolding, fall protect, elevated work platform required)
- whether the roof is suitable for mounting the array
- solar access for the site
- whether any shading will occur and its estimated effect on performance
- orientation and tilt angle of the roof
- where the inverter will be located
- location of AC switchboards
- whether any switchboard or metering alterations are required.

8 Energy yield

Australian systems are typically sold based on price or the size that will fit onto the available roof space.
Once the size, in kWp, is selected then the designer shall determine the system's energy output over one year (known as the energy yield).

There are many commercial tools available to assist in calculating energy yield, for example PV-GC, SunEye, PVSyst, Solar Pathfinder, etc. Some of these make an allowance for shading.
It is recommended to use one of these tools on the site visit to provide accurate estimates of energy yield.

8.1 Energy Yield Formula

The average yearly energy yield can be estimated as follows:

$$E_{sys} = P_{array\_STC} \text{ x } f_{man} \text{ x } f_{dirt} \text{ x } f_{temp} \text{ x } H_{tilt} \text{ x } \eta_{pv\_inv} \text{ x } \eta_{inv} \text{ x } \eta_{inv\_sb}$$

where:

E_{sys} = average yearly energy output of the PV array, in watt-hours
P_{array_stc} = rated output power of the array under standard test conditions, in watts
f_{man} = de-rating factor for manufacturing tolerance, dimensionless (*refer to section 4.2.1)*
f_{dirt} = de-rating factor for dirt, dimensionless *(refer to section 4.2.2)*
f_{temp} = temperature de-rating factor, dimensionless *(refer to section 4.2.3)*
H_{til} = Yearly (monthly) irradiation value (kWh/m^2) for the selected site (allowing for tilt, orientation
η_{pv_inv} = efficiency of the subsystem (cables) between the PV array and the inverter
η_{inv} = efficiency of the inverter dimensionless
η_{inv_sb} = efficiency of the subsystem (cables) between the inverter and the switchboard.

(NOTE: The above formula for energy yield could be rearranged to determine the size of the array, if the system is to be designed to provide a predetermined amount of energy per year, for example when a customer wants a system that meets their total annual energy usage.)

8.1.1 Manufacturer's output tolerance

The output of a PV module is specified in watts, with a manufacturing tolerance and is based on a cell temperature of 25°C (STC).

Example:

A 160W module has a manufacturer's tolerance of ±3%. The "worst case" adjusted output of the PV module is therefore 160W x 0.97 = 155.2W.

8.1.2 De-rating due to dirt

The output of a PV module can be reduced as a result of a build-up of dirt on the surface of the module.
The actual value of this de-rating will be dependent on the actual location but in some city locations this could be high due to the amount of pollution in the air. If in doubt, an acceptable de-rating would be 5%.

Example continued:

The de-rated module of 155.2W would be de-rated by a further 5% due to dirt: 155.2W x 0.95 = 147.4W.

8.1.3 De-rating due to temperature

As a minimum, in accordance with AS4059.2, the average temperature of the cell within the PV module can be estimated by the following formula:

$$T_{cell.eff} = T_{a.day} + 25^{\circ}\mathrm{C}$$

where

$T_{cell.eff}$ = average daily effective cell temperature, in degrees C

and

$T_{a.day}$ = daytime average ambient temperature (for the month of interest), in degrees C.

Array frames in stand-alone power systems are typically tilted at higher angles and the modules have good airflow. With rooftop grid-connected systems, higher temperatures have been observed.

For grid-connect systems the effective cell temperature is determined by the following formula:

$$T_{cell.eff} = T_{a.day} + T_{r}$$

where

T_{r} = effective temperature rise for specific type of installation.

$T_{a.day}$ = the daytime ambient temperature in °C

It is recommended that the following temperature rise (T_r) applies for different array frames:

- parallel to roof (<150mm standoff): +35°C
- rack-type mount (>150mm standoff): +30°C
- top-of-pole mount, free standing frame and frame on roof with tilt angle of about + 20 degrees to slope of roof: +25°C.

Solar modules each have different temperature coefficients. These typically range from +0.2%/°C to -0.5%/°C dependant on module technology. *(Refer to the manufacturer's datasheet for exact values).*

The de-rating of the array due to temperature will be dependent on the type of module installed and the average ambient maximum temperature for the location.

8.1.3.a Temperature de-rating formula

The temperature de-rating factor is calculated as follows:

$$f_{temp} = 1 + (\gamma \times (T_{cell.eff} - T_{stc}))$$

where

f_{temp} = temperature de-rating factor, dimensionless

γ = value of power temperature coefficient per degrees C (*see above)*

$T_{cell.eff}$ = average daily cell temperature, in degrees C
T_{stc} = cell temperature at standard test conditions, in degrees C.

(NOTE: The manufacturer's specified value of power temperature coefficient is applied – include the -ve sign as shown on the data sheet. The formula determines whether the temperature factor is greater or less than 1 due to actual effective temperature of the cell.)

Example continued:
Assume the average ambient temperature is 25 °C ($T_{a.day}$) and the module is polycrystalline and frame is parallel to roof but less than 150mm off roof.

The average daily effective cell temperature is:

$T_{cell.eff} = T_{a.day} + 35 = 25 + 35 = 60°C$

In the above formula the absolute value of the temperature coefficient (γ) is applied, this is -0.5%/°C and cell temperature at standard test conditions is 25 °C (Tstc)

Therefore the effective de-rating factor due to temperature is: 1 + [-0.5% X (60 – 25)] = 1 -17.5% = 0.825
The temperature de-rating becomes 82.5% of 147.4W or 121.6W.

8.1.4 Solar irradiation data

Solar irradiation data is available from various sources, such as the Australian Solar Radiation Data Handbook or the Meteorological Bureau. The units used are often MJ/m²/day. To convert to kWh/m²/day (PSH) divide by 3.6.

(NOTE: Grid-connected solar PV systems are typically mounted on the roof of the house or building. The roof might not be facing true north or at the optimum tilt angle. The PSH figure for the roof orientation (azimuth) and pitch (tilt angle) shall be used when undertaking the design.)

8.1.5 Effect of Orientation and Tilt

When the roof is not orientated true north and/or not at the optimum inclination, the output from the array will be less than the maximum possible.
Tables are available to download from solaraccreditation.com.au that contain the following information:

- the average annual daily total irradiation for various orientations (azimuth) and inclination (tilt) angles, represented as a percentage of the maximum value
- average daily total irradiation for various orientations and inclination angles for each month of the year.

These data tables were produced by consultancy Exemplary Energy, which also produces the Australian Solar Radiation Data Handbook.
The tables provide the designer with information on the expected reduction of the PV output as a percentage of the maximum possible output (when the array is located on a roof that is not facing the true north at an inclination equal to the latitude angle). The tables also provide the designer with information to calculate the energy yield of the average daily performance estimate in kWh for each month of solar generation.

Tables are available to download from solaraccreditation.com.au for the following major cities:

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

8.1.6 DC Cable loss

It is recommended that the maximum voltage drop between the PV array and the inverter is no greater than 3%.

Example continued:

The de-rated module of 121.6W would be de-rated by a further 3% due to DC cable loss: 121.6W x 0.97 = 118W.

8.1.7 Inverter efficiency

This is obtained from the inverter specifications.

Example continued (using an inverter efficiency specification of 90%):

The de-rated module of 118W would be de-rated by a further 10% due to inverter efficiency: 118W x 0.90 = 106.2W.

8.1.8 AC Cable loss

It is recommended that the voltage drop between the inverter and the main switch board not greater than 1%

Example continued:

The de-rated module of 106.2W would be de-rated by a further 1% due to AC cable loss: 106.2W x 0.99 = 105.1W.

8.2 Specific energy yield

The specific energy yield is expressed in kWh per kW_p and is calculated as follows:

$$SY = \frac{E_{sys}}{P_{array\_STC}}$$

To compare the performance of systems in different regions, shading loss must be eliminated from the calculation of energy yield for the sites being compared.

8.3 Performance ratio

The performance ratio (PR) is used to assess the installation quality. The performance ratio is calculated as follows:

$$PR = \frac{E_{sys}}{E_{ideal}}$$

where

E_{sys} = actual yearly energy yield from the system

E_{ideal} = the ideal energy output of the array.

The PV arrays ideal energy yield E_{ideal} can determined two ways.

Method 1:

$$E_{ideal} = P_{array\_STC} \times H_{tilt}$$

where

H_{tilt} = yearly average daily irradiation, in kWh/m^2 for the specified tilt angle

$P_{array..STC}$ = rated output power of the array under standard test conditions, in watts

Method 2:

$$E_{ideal} = H_{pv} \times \eta_{pv}$$

where

H_{pv} = actual irradiation that falls on the array surface area

η_{pv} = efficiency of the PV modules

and

$$H_{pv} = H_{tilt} \times A_{pv}$$

where

H_{tilt} = yearly average daily irradiation, in kWh/m^2 for the specified tilt angle

A_{pv} = total area of the PV array.

9 Inverter selection

The selection of the inverter for the installation will depend on:

- the energy output of the array
- the matching of the allowable inverter string configurations with the size of the array in kW and the size of the individual modules within that array
- whether the system will have one central inverter or multiple (smaller) inverters.

9.1 Multiple inverters

1. If the array is spread over a number of rooves that have different orientations and/or tilt angles then the maximum power points and output currents will vary. If economic, installing a separate inverter for each section of the array which has the same orientation and angle will maximise the output the total array.
   This could also be achieved by using an inverter with multiple maximum power point trackers (MPPTs).
2. Multiple inverters allow a portion of the system to continue to operate even if one inverter fails.
3. Multiple inverters allow the system to be modular, so that increasing the system involves adding a predetermined number of modules with one inverter.
4. Multiple inverters better balance phases in accordance with local utility requirements.

The potential disadvantage of multiple inverters is that in general, the cost of a number of inverters with lower power ratings is generally more expensive.

9.2 Inverter sizing

Inverters currently available are typically rated for:

- maximum DC input power i.e. the size of the array in peak watts
- maximum DC input current
- maximum specified output power i.e. the AC power they can provide to the grid.

9.3 Maximum DC input power

The maximum power of the array is calculated using the following formula:
Array Peak Power = Number of modules in the array x the rated maximum power (P_{mp}) of the selected module at STC.

9.4 Array peak power – inverter sizing

In order to facilitate the efficient design of PV systems the inverter nominal AC power output cannot be less than 75% of the array peak power and it shall not be outside the inverter manufacturers max input power specifications.

Example of a 2kW array and 4 inverters with different specification

	System 1	System 2	System 3	System 4
a) Proposed array peak power (eg 10 x 200W)	2000	2000	2000	2000
b) 75% of Proposed array peak power (Watts)	1500	1500	1500	1500
c) Inverter manufacturers' max input power (from spec sheet) (Watts)	2100	1900	2100	1900
d) Inverter manufacturers' nominal AC power rating (Watts)	1700	1700	1200	1200
Is manufacturers' max input power greater than array peak power (c >a)?	Yes	No	Yes	No

Is inverter nominal AC power greater than 75% of proposed array peak power (d > b)	Yes	Yes	No	No
Proposed array peak power – Inverter sizing acceptable	Yes	No	No	No

Where the maximum DC input rating of the inverter is **not** specified the designer shall match the array to the inverter allowing for the de-rating of the array (see section 8.1.1 to 8.1.4).

9.5 *Array de-rating formula*

In the section on de-rating module performance, the typical PV array output in watts is de-rated due to:

- manufacturers tolerance of the modules
- dirt and temperature.

9.5.1 Inverter with crystalline modules

Based on figures of:

- 0.97 for manufacture
- 0.95 for dirt
- 0.825 for temperature (based on ambient of 35°C). (Refer to section 8.1.3)

The de-rating of the array is: 0.97 x 0.95 x 0.825 = 0.76
As a result of this type of de-rating being experienced in the field, the inverter can easily be rated 76% of the peak power of the array.

9.5.2 Inverter with thin film modules

The temperature effect on thin film modules is less than that on crystalline modules. Assuming the temperature coefficient is only 0.1% then the temperature de-rating at ambient temperature of 35°C is 0.965
Based on figures of :

- 0.97 for manufacturer
- 0.95 for dirt
- 0.965 for temperature (based on ambient of 35°C).

The de-rating of the array is: 0.97 x 0.95 x 0.965 = 0.889

As a result of this type of de-rating being experienced in the field, the inverter can easily be rated 89% of the peak power of the array.

Example:
Assume the array comprises 16 of the 160Wp crystalline modules then the array peak power = 16 x 160 = 2.56kW.
The inverter should have a maximum DC input rating of at least of 2.56kW and a nominal AC power output rating of 1.92kW (2.56kW X 75%)
If the manufacturer **does not** provide DC input specifications then following the above guidelines:
This array can be connected to an inverter with an output rating of: 0.76 x 2.56kW = 1.95kW (for crystalline modules)
If thin film modules are used then the inverter could have an output rating of: 0.889 x 2.56kW = 2.27kW

9.6 *Matching inverter/array voltage*

The output power of a solar module is affected by the temperature of the solar cells. In crystalline PV modules this effect can be as much as -0.5% for every 1 degree variation in temperature.
(*NOTE: for other PV cell technologies the manufacturers data must be used).*

The temperature de-rating factor for the output power is:

$$f_{temp} = 1 + \left[\gamma \times \left(T_{cell\_eff} - T_{STC}\right)\right]$$

where

f_{temp} = temperature de-rating factor, dimensionless
γ = power temperature co-efficient per °C (typically 0.005 for crystalline cells)
$T_{cell.eff}$ = average daily cell temperature, in °C (see section on temperature effect on modules)
T_{stc} = cell temperature at standard test conditions, measured in °C.

The maximum power point voltage and open circuit voltage are affected by temperature and the temperature co-efficient as a % is typically very similar to the power coefficient.

The - maximum - effective cell temperature

$$T_{cell\_eff} = T_{ave\_amb} + Tr\,^{0}\mathrm{C}$$

Where

T_{cell_eff} = the effective cell temperature in °C
T_{ave_amb} = the daytime ambient temperature in °C
T_r = the temperature rise dependent on array frame type in °C
(refer to section on temperature de-rating of solar array for typical values)

The above can also be applied as the de-rating factor for open circuit voltage and maximum power point voltage. With the odd exception, grid-interactive inverters include maximum power point trackers (MPPTs).

Many of the inverters available will have a voltage operating window. If the solar array voltage is outside this window then either the inverter will not operate or the output power of the system will be greatly reduced.
Minimum and maximum input voltages will be specified by the manufacturer. The maximum voltage is the voltage where above this the inverter could be damaged. Some inverters will nominate a voltage window where they will operate and then a maximum voltage, higher than the maximum operating voltage of the window, which is the voltage where the inverter could be damaged.

For the best performance of the system the output voltage of the solar array should be matched to the operating voltages of the inverter. To minimise the risk of damage to the inverter, the maximum voltage of the inverter shall never be reached.

As stated earlier, the output voltage of a module is effected by cell temperature changes in a similar way as the output power .

The PV module manufacturers will provide a voltage temperature co-efficient.
It is generally specified in V/°C (or mV/°C) but it can be expressed as a %/°C .

To design systems where the output voltages of the array do not fall outside the range of the inverter's DC operating voltages and maximum voltage (if different), the minimum and maximum daytime temperatures for that specific site are required.

9.7 Minimum voltage window

When the temperature is at a maximum then the maximum power point voltage (V_{mp}) of the array should not fall below the minimum operating voltage of the inverter. The actual voltage at the input of the inverter is not just the V_{mp} of the array, the voltage drop in the DC cabling must also be included when determining the actual inverter input voltage.

The temperature de-rating factor can be adapted to determine the maximum power point voltage at a specified temperature.

$$V_{mp\_cell\_eff} = V_{mp\_STC} + \left[\gamma_v \times \left(T_{cell\_eff} - T_{STC}\right)\right]$$

Where:

$V_{mp\_cell.eff}$ = Maximum power point voltage at effective cell temperature, in volts
V_{mp-stc} = Maximum power point voltage at STC, in volts
γ_v = Voltage temperature (V_{mp}) coefficient in volts per °C
T_{cell_eff} = cell temperature at specified ambient temperature, measured in °C
T_{stc} = cell temperature at STC, measured in °C

To maximise the performance of the array, the minimum array voltage should never fall below the minimum voltage operating window of the inverter. The number of modules in the string should be selected so that the maximum power voltage of the array for the highest temperature expected is above the minimum voltage operating window of the inverter.

Since the daytime ambient temperature in some areas of Australia can reach or exceed 35°C it is recommended that maximum effective cell temperature of 70°C is used.

Worked example:
Assume that the minimum voltage window for an inverter is 140V.
The module selected has a rated MPP voltage of 35.4V and a voltage (V_{mp}) co-efficient of -0.177V /°C
Using equation for $V_{mp\_cell.eff}$ above, the minimum MPP voltage at a maximum effective cell temperature of 70°C, the temperature de-rating is:

$V_{min\_mpp} = 35.4 + (-0.177 \times (70- 25)) = 27.4V$

If we assume a maximum voltage drop in the cables of 3% then the voltage at the inverter for each module would be 0.97 x 27.4 = 26.6V

This is the effective minimum MPP voltage input at the inverter for each module in the array, $V_{min\_mpp\_inv}$

The minimum number of modules in the string can be determined by the following equation

$$N_{\min\_per\_string} = \frac{V_{inv\_\min}\ (\text{V})}{V_{\min\_mpp\_inv}\ (\text{V})}$$

where

V_{inv_min} = the minimum inverter input voltage
$V_{min\_mpp\_inv}$ = the effective minimum MPP voltage of a module at the inverter at maximum effective cell temperature

The minimum voltage allowed at the inverter, in this example, is 140V.
The MPP voltage rises with increases in irradiance. Since the array is typically operating with irradiance levels less than 1kW/m² then the actual MPP voltage would be reduced *(NOTE: the exact variation is dependent on the quality of the solar cell so it is recommended that a safety margin of 10% is used.)*

In the worked example above, a minimum inverter voltage of 1.1 x 140V = 154V should be used.

The minimum number of modules in a string is:
$N_{min\_per\_string}$ = 154 / 26.6 = 5.8 rounded up to 6 modules.

9.8 Maximum voltage window

At the coldest daytime temperature the open circuit voltage of the array shall never be greater than the maximum allowed input voltage for the inverter. The open circuit voltage (Voc) is used because this is greater than the MPP voltage and it is the applied voltage when the system is first connected (prior to the inverter starting to operate and connecting to the grid).

NOTE: Some inverters provide a maximum voltage for operation and a higher voltage as the maximum allowed voltage. In this situation, the MPP voltage is used for the operation window and the open circuit voltage for the maximum allowed voltage.

In early morning, at first light, the cell temperature will be very close to the ambient temperature because the sun has not had time to heat up the module.
Therefore, the lowest daytime temperature for the area where the system is installed shall be used to determine the maximum Voc. This is determined by the following equation

$$V_{\max\_oc} = V_{oc\_STC} + [\gamma_v \times (T_{\min} - T_{STC})]$$

where
V_{max_oc} = Open circuit voltage at minimum cell temperature , volts
V_{oc_STC} = Open circuit voltage at STC, volts
γ_V = voltage temperature V_{oc}co-efficient ,- V/°C
T_{min} = expected min. daily cell temperature, °C
T_{STC} = cell temperature STC, °C

In many areas of Australia, the minimum daytime ambient temperature can be less than 0°C while there are areas where it never falls below 20°C.

Note: It is recommended that the designer use the minimum temperature for the area where the system will be installed.

In the worked example, assume the minimum effective cell temperature is 0°C:
$V_{oc\text{-}stc}$ is 43.2V
and the maximum open circuit voltage - at minimum effective temperature – is

$$\begin{aligned} V_{oc\_max} &= 43.2 + (-0.16 \times (0 - 25)) \\ &= 43.26 + (-0.16 \text{ x } -25) \\ &= 43.2 + 4 \\ &= 47.2\text{V} \end{aligned}$$

For our example, assuming the maximum voltage allowed by the inverter is 400V (V_{inv_max})

The maximum number of modules in the string, $N_{max\_per\_string}$, is determined by the following equation:

$$N_{\max\_per\_string} = \frac{V_{inv\_\max}\ \text{(V)}}{V_{oc\_\max}\ \text{(V)}}$$

= 400 / 47.2 = 8.47 rounded down to 8 modules

In the example presented, the PV string must consist of between 6 - 8 modules only.

In the worked example, for sizing the inverter 16 modules were required.

Therefore we could have two parallel strings of 8 modules.

9.9 Inverter DC input current

Ensure that the total short circuit current or the array does not exceed the max DC input current specification of the inverter.

9.10 Effects of shadows

In towns and cities where grid-connected PV systems will be dominant, the roof of the house or building will not always be free of shadows during parts of the day. Care should be taken when selecting the number of modules in a string because shading could result in the maximum power point voltage at high temperatures being below the minimum operating voltage of the inverter.