CIS Solar Photovoltaic Standard

The University of Sydney

Engineering & Sustainability Team

Document Control

Document Name:	CIS Solar Photovoltaic Standard
Document ID:	CIS-PLA-STD-Photovoltaic Standard
Document Status:	Final
Version No:	001
Author(s): **Position:** **Signature:**	Sue Kennewell Sustainability Officer
Document Owner:	Engineering & Sustainability Team
Approved by: **Position:** **Signature:**	Greg Robinson Director of CIS
Date Approved:	10 November 2015
Date of Issue:	10 November 2015
Issued by:	Campus Infrastructure & Services

Contents

1 PURPOSE 1
2 SCOPE 1
3 GLOSSARY OF TERMS 1
4 ABBREVIATIONS 4
5 AUTHORITIES & RESPONSIBILITIES 4
6 DESIGN & CONSTRUCTION REQUIREMENTS 4
6.1 COMPLIANCE WITH AUSTRALIAN STANDARDS AND GUIDELINES 4
6.2 SYSTEM PLANNING 5
6.2.1 SYSTEM PROVIDER 5
6.2.2 SITE ASSESSMENT 5
6.2.3 SAFE ROOF ACCESS 6
6.2.4 SYSTEM DESIGN 6
6.2.5 LOCATION OF PV ARRAY 8
6.2.6 SYSTEM SIZE 8
6.2.7 ARRAY AND INVERTER MATCHING 8
6.2.8 DISTRIBUTION NETWORK OPERATOR APPROVAL 9
6.3 SYSTEM EQUIPMENT REQUIREMENTS 9
6.3.1 PV MODULE REQUIREMENTS 9
6.3.2 INVERTER REQUIREMENTS 11
6.3.3 MICRO-INVERTER REQUIREMENTS 12
6.3.4 DC POWER OPTIMISER REQUIREMENTS 12
6.3.5 MOUNTING SYSTEM REQUIREMENTS 12
6.3.6 MONITORING SYSTEM REQUIREMENTS 13
6.3.7 BALANCE OF SYSTEM COMPONENT REQUIREMENTS 13
6.4 SYSTEM INSTALLATION 15
6.4.1 PV MODULE INSTALLATION 15
6.4.2 INVERTER INSTALLATION 16
6.4.3 CABLE MANAGEMENT/WIRING 16
6.4.4 DC ISOLATORS 17
6.4.5 ROOF PENETRATION BY PV SYSTEM 17
6.4.6 PV SYSTEM SIGNAGE 17
6.4.7 LIGHTNING PROTECTION 18
6.4.8 EARTHING 18
6.4.9 SYSTEM WORKMANSHIP WARRANTY 19

6.5 REMOVAL OF SYSTEM FOR REPAIR WORK 19
6.6 PV SYSTEM UPGRADES 19
7 COMMISSIONING 19
8 DEFECTS LIABILITY PERIOD 19
9 DOCUMENTATION & RECORDS 20
9.1 DESIGN SUBMISSION 20
9.2 COMMISSIONING DOCUMENTATION 20
9.3 PRACTICAL COMPLETION 20
10 OPERATIONS AND MAINTENANCE 21
11 AUTHORISATION OF VARIATIONS 21
12 QUALITY CONTROL 21
13 REFERENCES 21
14 NOTES 22
15 ATTACHMENTS 22
ATTACHMENT 1: DOCUMENTATION CHECKLIST 23
ATTACHMENT 2: PV ARRAY TILT AND ORIENTATION 25
ATTACHMENT 3: SYSTEM SIZING CHECKLIST 27
ATTACHMENT 4: ARRAY AND INVERTER MATCHING 28
ATTACHMENT 5: DC ISOLATOR RATING AND INSTALLATION 30
ATTACHMENT 6: INSTALLING PV MODULES ON ROOF 32
ATTACHMENT 7: INVERTER STATION EQUIPMENT CONFIGURATION 34
ATTACHMENT 8: ROOF PENETRATIONS 36
ATTACHMENT 9: SYSTEM SIGNAGE 38
ATTACHMENT 10: PV SYSTEM COMMISSIONING 46
ATTACHMENT 11: PV SYSTEM MAINTENANCE 1

1 PURPOSE

The CIS Photovoltaic Standard sets out the University of Sydney's minimum requirements for the design, construction and maintenance of Photovoltaic (PV) Systems. The purpose of this standard is to ensure that the specified information and practical deliverables for the procurement, installation and operation of PV systems are of a consistently high standard.

2 SCOPE

This standard covers the requirements and recommendations for grid connected PV solar power systems, including PV systems with batteries. This document is in relation to the selection and provision of key system equipment, pre-installation requirements including location/siting assessment, installation practices, and post installation activities, including operation and maintenance, and commissioning requirements to deliver a consistent quality of PV system installed.

3 GLOSSARY OF TERMS

Advanced Utilities Monitoring System (AUMS)	The AUMS is the University's automated meter reading system. The system consists of a cloud based user interface that accesses utility consumption data (typically 15 minute data) from the AUMS database. The architecture of the AUMS is set out in the CIS AUMS Standard.
Alternating Current (AC)	Electricity in which the polarity of the current is periodically reversed.
Altitude	The height of the Sun from the horizon.
Azimuth	The position of the Sun in relation to the cardinal directions. The solar industry standard is to express azimuth clockwise from true north (0°–360°); however it can also be quoted with a direction, east or west (i.e. 0°–180°E or 0°–180°W).
Battery	A container consisting of one or more cells, in which chemical energy is converted into electricity and used as a power source.
Cell efficiency	The fraction of electrical power produced by a solar PV cell per amount of light energy hitting the cell.
Circuit	A circuit is the path that current flows from one charged point to another.
Circuit breaker	A mechanical device which will open a circuit under fault conditions. When too much current passes through, the device will open and prevent current flow. The circuit breaker can then be manually operated to close the circuit.
Combiner box	An electrical component for combining and housing the wiring from the PV array.
Current	Current is the movement of charge and is measured in amperes (A). Conventional current is the 'flow' from positive to negative, and is opposite to electron flow. It is used throughout this publication.
Direct Current (DC)	Electricity in which the current always moves in the same direction.
DC power optimisers (DC conditioning units)	DC to DC converters connected to individual or small groups of PV modules, usually incorporating a maximum power point tracker.

Energy	The amount of electric energy transferred, a product of power and time. Energy is measured in watt hours (Wh) and is calculated using: $E = P \times t$
Energy Yield	A photovoltaic system's energy output measured over a given period of time is its yield. This value is a common measurement as it is used to indicate performance as well as forming the basis of income from STCs (see Small Scale Technology Certificates).
Equipotential bonding	Equipotential bonding (or protective earthing) is the connecting of conductive metalwork electrically to the Earth so that it is at the same voltage (potential) as Earth throughout. This is required for safety reasons to protect people from electric shocks.
Extra Low Voltage (ELV)	Electrical systems that operate under 120 V DC (ripple free) or 50 V AC. ELV systems do not require an electrical license to be installed or worked on (see Low Voltage).
Functional earthing	The electrical connection of PV positive or negative conductors to the Earth. This is designed to ensure optimal performance of the PV array, but it is required only if specified by the manufacturer.
Fuse	A device that protects conductors from excessive current. The fuse is rated to carry a certain current, and when this current is exceeded the fuse will open the circuit (by melting).
Grid-connected PV system	A PV system which exports electricity to an electrical grid.
Irradiation (or Insolation)	The total amount of solar radiation available per unit area over a specified time period such as one day. It is the sum of irradiance values over a time period and is often measured in kWh/m2/year or MJ/m2/day. It is a measure of energy.
Islanding	The scenario where a distributed generator continues to supply power to a part of the electricity network (an 'island') when that part of the network is no longer supplied with utility-generated ('grid') power.
Junction box	A box containing a junction of electric wires or cables.
Kilowatt peak (kWp)	A non-SI unit used in the solar industry to describe the nominal power of a solar PV system: it refers to the peak output of the system under standard test conditions.
Low Voltage (LV)	Electrical systems that operate over 120 V DC (ripple free) or 50 V AC. Systems of these voltages require an electrical license to operate or install.
Maximum Power Point (MPP)	The PV module operation point where the current and voltage generated by the PV module gives the maximum power. It occurs when the load resistance is equal to the internal resistance of the PV cell.
Maximum Power Point Tracker (MPPT)	An electronic device included within the inverter that alters the PV array's electrical output so that it is performing at the maximum power possible at any given time.
Micro Inverter	Small inverters connected to only one or two PV modules.
Module efficiency	The fraction of electrical power produced by the PV module per amount of light energy hitting the module. This is typically lower than cell efficiency due to losses from reflection from glass etc.

Monocrystalline solar cells	The most efficient and most expensive solar cells available. They have a smooth monochromatic appearance.
Multimode Inverter	An inverter that is able to operate as a grid-interactive inverter as well as an off-grid inverter, supplying specific loads during disconnection from the grid.
Nominal	A nominal value is a reference value used to describe batteries, modules or systems. Therefore, it is not an exact value. For example, the nominal voltage of a 72-cell solar module is 24 V but the open circuit voltage (Voc) for the same module can be 45.6 V and the maximum power voltage (Vmp) can be 35 V.
Open Circuit	An open circuit is where the current path is broken so that the current is equal to 0.
Passive Protection	The over and under voltages, and the over and under frequency trip settings in the inverter.
Photovoltaic (PV)	The process which allows a device to creates electricity when sunlight hits its surface.
Power	Power is the rate at which electric energy is transferred. Power is measured in watts (W), and is calculated using Power = Voltage (V) x Current (I).
Power Conversion Equipment (PCE)	A device that converts electrical power from one kind of power to another. In the context of PV systems this usually refers to an inverter.
PV array	Strings of PV modules are electrically connected in parallel to form an array. Also called a solar array.
PV module	A unit consisting of PV cells that are physically and electrically connected. These cells are held together by a frame and covered by a protective substance such as glass. Also called a solar module.
PV string	When PV modules are connected in series they form a string.
PV system	The PV array and all associated equipment required to make it work. Also called a solar electric system.
Resistance	The opposition to current; measured in ohms (Ω).
Short Circuit	A short circuit is where the current is flowing in a closed path across the source terminals.
Small scale technology certificates (STCs)	The Australian Government's Small Scale Renewable Energy Scheme enables small PV systems to produce these certificates to help offset the initial cost of a PV system. Each STC is equivalent to 1MWh electricity generated. Their value varies depending on size of system, location, and the method through which the STC is sold.
Solar Modules	See PV module.
Standard Test Conditions (STC)	Standardised test conditions which make it possible to conduct uniform comparisons of PV modules by different manufacturers.
Surge protection	Devices or appliances that are used to protect electrical devices from voltage spikes.
Switch-Disconnector (or	Mechanical switching device capable of making, carrying and breaking currents in normal circuit conditions and, when specified, in given operating overload

Isolator)	conditions.
Time of use tariff	The consumer pays the electricity retailer a different tariff depending upon what time of day the electricity is used. For example, the consumer will pay more for electricity used during peak times such as the evening and less during off-peak times such as overnight.
Voltage	The electrical potential difference between two points. Voltage is measured in volts (V).
Uninterruptible power supply	Provides short term power back up for important applications, such as IT and telecommunications.
Zero export meter/device	A device that limits or prevents the quantity of solar power that can be exported onto the grid by adjusting inverter operating parameters.

4 ABBREVIATIONS

CIS – Campus Infrastructure Services

5 AUTHORITIES & RESPONSIBILITIES

This standard is owned by CIS. It is approved and signed-off by the Director of CIS. The CIS Engineering and Sustainability Team are responsible for maintaining the standard and keeping it up-to-date. The Standard must be reviewed biennially.

6 DESIGN & CONSTRUCTION REQUIREMENTS

The contractor is required to perform decommissioning and demolition of all redundant services and infrastructure in the works area. Remove any hazardous materials in accordance with the CIS Resource Recovery and Waste Management Standard.

6.1 Compliance with Australian Standards and Guidelines

The PV system must be designed and installed in accordance with the most recent Australian Standards and guidelines including, but not limited to, the following:

Australian Standard AS/NZS 1170.2	Structural Design Actions - Wind Actions
Australian Standard AS/NZS 3000	Wiring Rules
Australian Standard AS/NZS 3008	Electrical Installation – Selection of Cables
Australian Standard AS 4777	Grid connection of energy systems via inverters (Parts 1, 2 and 3 inclusive)
Australian Standard AS/NZS 5033	Installation and safety requirements for photovoltaic (PV) arrays
New South Wales Service and Installation Rules	
Electricity Distributor Service and Installation Rules	
Clean Energy Council	Grid Connected Solar PV systems – Design guidelines for accredited installers
Clean Energy Council	Grid Connected Solar PV systems – install and supervise guidelines for accredited installations
Australian Building Codes Board	Building Code of Australia
University of Sydney	CIS Electrical Services Standard

University of Sydney	CIS Roofing and Guttering Standard
University of Sydney	CIS Advanced Utilities Monitoring System Standard
University of Sydney	CIS Asset Identification and Labelling Standard

In addition, grid-connected PV systems with energy storage must comply with the following standards:

Australian Standard AS 2676	Guide to the Installation, Maintenance, Testing and Replacement of Secondary Batteries in Buildings
Australian Standard AS 4086.1	Secondary Batteries for Use with Stand-Alone Power Systems – General Requirement
Australian Standard AS 4086.2	Secondary Batteries for Use with Stand-Alone Power Systems – Installation and maintenance
Australian Standard AS/NZS 4509.1	Stand-Alone Power Systems – Safety and installation
Australian Standard AS/NZS 4509.2	Stand-Alone Power Systems – System Design
Australian Standard AS 62040 (All Parts)	Uninterruptible Power Systems (UPS)

6.2 SYSTEM PLANNING

6.2.1 SYSTEM PROVIDER

Unless identified otherwise by CIS, the system provider must carry out the design, supply, installation and commissioning of the PV system and all necessary ancillary work to deliver the completion of the PV system as specified.

Where products containing hazardous materials are proposed, e.g. Cadmium Telluride, Lithium Ion batteries etc. CIS may require that the system provide recycle or dispose of key system components at end of life. For CIS to assess this requirement, the system provider will provide recycling and/or disposal information for the PV modules, Inverters and batteries (if applicable).

In carrying out the installation of grid-connected solar power systems, the system provider must be required to undertake the work in accordance with the *Work Health and Safety Act 2011*. In addition, personnel carrying out work relating to the PV system must hold appropriate licenses, accreditations and certificates. Specifically:

- The designer of any PV system must be fully accredited by the Clean Energy Council (CEC) of Australia;
- At least one person undertaking installation work must have full CEC installer accreditation;
- All Low Voltage electrical work (voltage >120V DC or >50V AC) must be carried out by licensed electricians.

6.2.2 SITE ASSESSMENT

A site assessment of the installation site should be carried out prior to the installation.

As a minimum, the following should be assessed:

- Suitability of building roof for system installation by taking into consideration:
    - Solar access e.g. roof orientation and pitch, shading from objects on roof;
    - Available space for PV modules;
    - Roof condition including likelihood of repair in the next 10 years;
    - Structural integrity of roof structure to bear extra weight and wind loading of the proposed solar installation[1];

  - Suitability of the roof as a whole for the proposed installation work, such that no damage is likely to occur to the university infrastructure during installation and maintenance of the system.
- Suitability of existing AC mains supply:
  - Rating of electrical distribution board;
  - Identify if upgrades to electrical distribution board (EDB) are needed to accommodate switches and/or reduce losses;
  - Confirm that potential voltage rise will not exceed required values.
- Solar resource:
  - Ensure that there are accurate insolation data for the site: taking into account location specific factors including shading from surrounding topography and buildings and local weather patterns.
- Availability of space for installation of proposed PV system components in accordance with installation requirements e.g. restriction of access to inverters and space needed for the PV array. See *6.4.1.3 PV module spacing* and *6.4.2.1 Inverter station location selection.*

[1] *Please note: if a ballast system is to be installed, signed structural engineer's certification must be obtained: for*

a) the roof's ability to support the ballast system and array components
b) the ballast requirements to adequately secure the array
c) the suitability of the roof substrate to securely mount the ballast to

6.2.3 SAFE ROOF ACCESS

A permanent safe roof access system must be provided to facilitate ongoing inspection and maintenance of the system.

The array layout must be designed so that no more than one other panel must be removed in order to test any panel in the array.

Safe roof access systems must be designed and installed in accordance with the CIS Roofing and Guttering Standard.

6.2.4 SYSTEM DESIGN

The design of the PV system must meet requirements as set out by the *Clean Energy Council Grid Connected Solar PV systems – Design guidelines for accredited installers.*

To prevent circulating currents, reduce mismatch losses and improve PV array energy yield, all PV strings connected in parallel to the same inverter input must have less than 5% voltage mismatch and have similar rated electrical characteristics.

The designer of the PV system must provide single line diagrams similar to Figure 1, including electrical ratings of all isolators and switches etc.

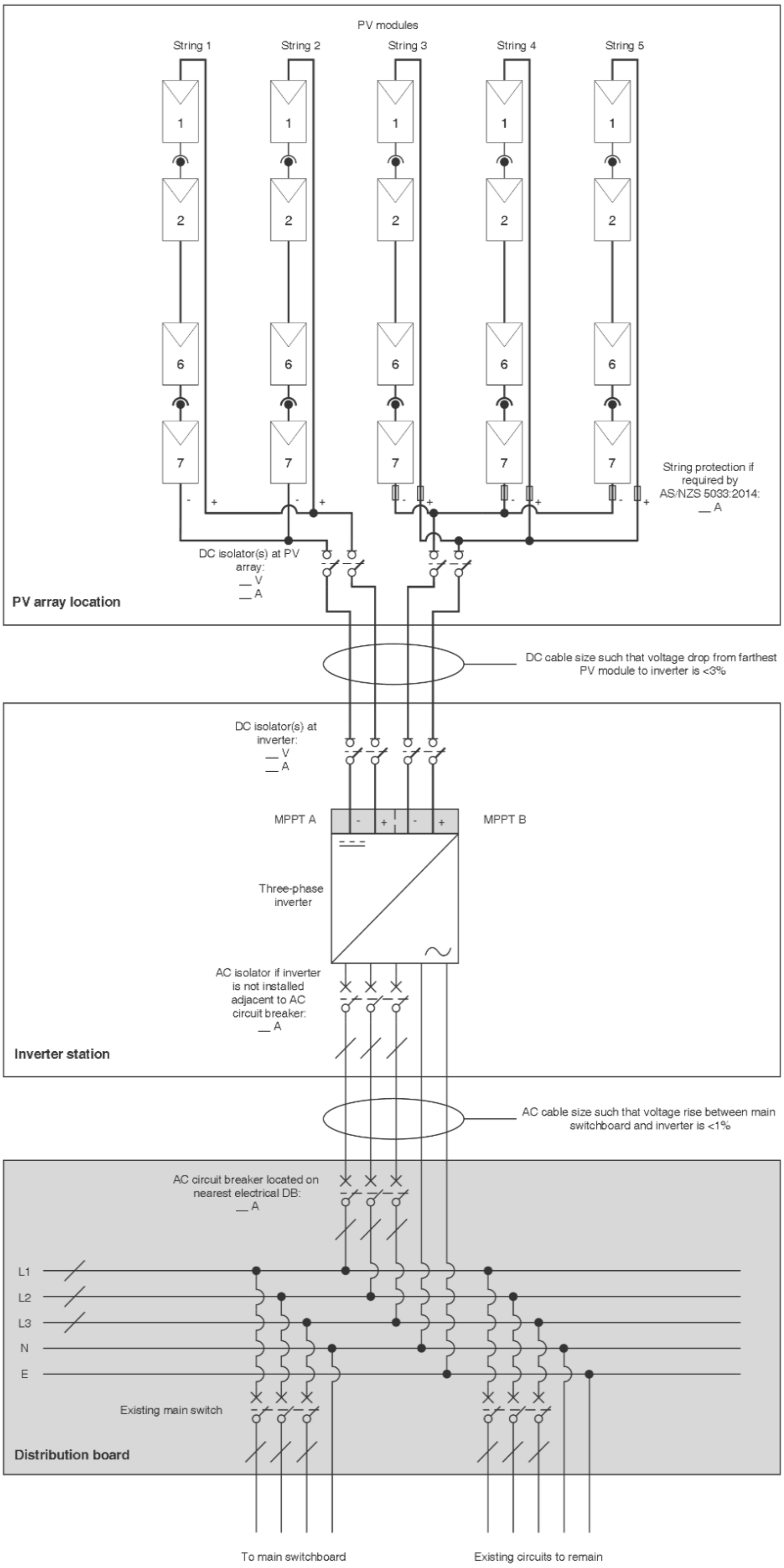


Figure 1: Single line diagram of three phase PV system

6.2.5 LOCATION OF PV ARRAY

The PV modules must be arranged so that they are grouped together where possible and are symmetrically or geometrically ordered.

Modules connected in the same string must be arranged so that their tilt and orientation are within $\pm 5^\circ$ of each other. This does not include micro-inverters and DC power optimisers connected to individual modules.

The location of the PV array should be designed to maximise annual solar generation:

- If flush mounting system is used, the array should be placed on roofs with a northerly aspect. All flush mounted arrays must achieve a minimum tilt of 10° from horizontal;
- If raked mounting system is used, the PV modules should be inclined to the same angle as the angle of latitude of the site $\pm 10^\circ$ and oriented so that panels face due north;
- If a north-facing roof is not available, installing on east or west facing roofs is permissible provided the system generation estimate meets the specified system size. See 6.2.6 System size for requirements.

The PV array should be arranged such that shading of PV modules by nearby buildings, trees, obstacles or the PV modules themselves between the hours of 9:00am and 3:00pm during all summer and winter months is minimised.

See *Attachment 2: PV Array Tilt and Orientation* for more information.

6.2.6 SYSTEM SIZE

The PV system size must be provided as both the sum of the PV array nominal capacity rating under Standard Test Conditions in kilowatt peak (kWp), and the sum of the nominal power output of all inverters in the system in kilovolt-ampere (kVA).

The system must be sized to minimise export to the electricity grid and to maximise the amount of onsite energy offset and economic benefit of the system. Unless otherwise specified by CIS, the PV system capacity must be determined from the energy usage of the CIS building; the system provider must propose a system size and provide payback calculations.. This information should reference the site's existing power bills, and interval meter data as the basis for these calculations, or for new buildings, an estimate of the predicted load profile at the connection point.

The expected operating life of the system should be at least 20 years. For the purposes of estimating the cost of ongoing system maintenance, assume that The University will carry out a system operation and maintenance inspection every year. Ongoing system costs should include inverter replacement every 10 years.

To aid in the accuracy of the above, the system provider should obtain the following information from CIS:

- Electricity usage and load profile;
- Cost of electricity during the hours of generation

See *Attachment 3: System sizing checklist* for assistance in system sizing.

6.2.7 ARRAY AND INVERTER MATCHING

The *CEC Grid Connected Solar PV systems – Design guidelines for accredited installers Section 9. Inverter selection* must be adhered to, particularly:

- Inverter maximum MPPT DC voltage, with a 5% safety margin subtracted, must be greater than the open-circuit voltage (Voc) of PV strings at the lowest temperature expected for the location;
- Inverter minimum MPPT DC voltage, with a 10% safety margin added, must be less than the Vmp of PV strings at the highest temperature expected for the location;

The inverter and PV array must be sized so that:

- The PV array capacity rating is greater than 95% of the inverter's nominal AC power rating;
- The inverter nominal AC power rating is greater than 75% of the PV array capacity rating.

See *Attachment 4: Array and Inverter Matching* for more information.

6.2.8 DISTRIBUTION NETWORK OPERATOR APPROVAL

The system provider must apply for, and obtain, the approval for connection of the proposed system by the relevant electricity distribution network service provider (DNSP) prior to installation of the PV system.

The system provider must meet all requirements set out by *NSW Service and Installation rules* and DNSP connection requirements. In particular:

- Voltage rise calculation must be carried out by the PV system provider to ensure that the percentage voltage rise at the installation is within limits set by AS 4777, NSW *service and installation rules* and DNSP requirements;
- Systems having a generation capacity greater than 5kW or AC current rating above 20A must not be connected to a single phase installation unless prior approval is received from the DNSP;
- The system provider must comply with a DNSP request for additional grid protection equipment.

The system provider must provide the reprogramming or replacement of existing MRIM or BASIC meters to facilitate bi-directional metering, complying with DNSP requirements. Meter selection must meet the requirements of the CIS Electrical Services Standard. All meters must be Modbus enabled and fully integrated to the University’s Advanced Utilities Monitoring System.

System provider must submit all paperwork and be responsible for liaison with the DNSP until the DNSP has offered a connection agreement and the agreement has been accepted by CIS. A copy of the connection agreement and all paperwork submitted to the DNSP must be included in the system documentation.

The cost of the interconnection of the PV system to the network, including equipment, processing charges and labour, must be included in the system provider’s quotation.

6.3 SYSTEM EQUIPMENT REQUIREMENTS

6.3.1 PV MODULE REQUIREMENTS

All PV modules proposed in a single PV system should have the same manufacturer and model.

The PV modules proposed must have the below requirements or better:

6.3.1.1 Certification

The PV modules supplied must be compliant with AS/NZS 5033

Crystalline photovoltaic modules (monocrystalline and multi/poly-crystalline): must be certified to IEC-61215.

Thin film photovoltaic modules (amorphous, cadmium telluride, copper indium gallium selenide, etc.): must be certified to IEC-61646.

All PV modules must be certified to IEC-61730 and must be listed on the Clean Energy Council approved PV modules list at time of installation. The Fire Test MST-23 must be carried out as part of the IEC 61730-2 testing and IEC 61730 certification. Modules installed on buildings must be listed as fire tested on the approved PV modules list at time of installation.

6.3.1.2 Equipment Class

PV modules must be Class A as defined by AS/NZS 5033

6.3.1.3 Protection Rating

PV module junction boxes that are exposed to the environment must be at least IP65 compliant in accordance with AS 60529 and must be UV resistant.

PV modules installed in a coastal environment or areas with high agricultural activities must be certified to the following IEC standards respectively:

IEC 61701 Ed 2.0 *Salt mist corrosion testing of photovoltaic (PV) modules*
IEC 62716 Ed 1.0 *Ammonia corrosion testing of photovoltaic (PV) modules*

Preference should be given to PV modules certified to the above IEC standard in all installations.

6.3.1.4 Temperature Coefficient

Maximum allowable temperature coefficient of maximum power is -0.5% / °C.

6.3.1.5 Module Efficiency

Monocrystalline: > 15%

Multi/poly-crystalline: > 14%

Thin film: > 9%

6.3.1.6 Operating Temperature

Operating module temperature -20°C to +80°C.

6.3.1.7 Mechanical Protection

Hailstone impact testing: Required

Minimum permissible wind load rating: 2.4KPa

Minimum permissible snow/mechanic load: 5.4KPa

6.3.1.8 Connectors and Cables

Connectors must be compliant with EN 50521 (2012). Datasheet and/or installation manual must indicate the make and model of the connector.

Cabling must comply with PV1-F requirements.

6.3.1.9 Warranty

Minimum manufacturer's workmanship Warranty: 10 years

Minimum manufacturer's power warranty: 10 years at 90% power output and 25 years at 80% power output or better.

6.3.2 INVERTER REQUIREMENTS

6.3.2.1 Selection of Inverter

Transformerless inverters are not to be used if the PV module selected requires functional earthing (i.e. connection of one of the PV array conductors to earth).

Inverters installed in an outdoor environment should have Ingress Protection of IP54 or greater.

6.3.2.2 Certification

The inverter(s) supplied must be compliant to AS 4777.2, IEC 62109-1 and IEC 62109-2. The inverter(s) must also be listed on the Clean Energy Council's list of compliant inverter and power conversion equipment.

6.3.2.3 Technical Requirements

The inverter must be provided with a Modbus output, and protocol converter (if required) to facilitate a wired connection of the inverter to the AUMS, via the University's ICT network.

The inverter must meet all requirements as specified by AS 4777 and AS/NZS 5033 including the following requirements:

- Voltage regulation: +10%/-6% of nominal voltage or as directed by DNSP
- Total harmonic distortion of output current: < 5%
- The inverter must be capable of autonomously synchronising with the existing grid voltage.
- Anti-Islanding protection: both active and passive protection required.
  - The over/under voltage and frequency protection settings must adhere to limits specified by the DNSP, NSW *Installation and Service Rules 8.6.14 Passive Protection* and AS 4777.
- Voltage and Frequency protection: to AS 4777.1: requirements.
- Inverter transient voltage limit: to AS 4777.2 requirements.
- Earth fault alarm system must be provided to IEC 62109-2 ed. 1 *13.9 fault indication* requirements
  - The earth fault alarm should be installed such that any fault indication is detectable by the building's administrative office and/or CIS.

Inverter must meet any DNSP and AS 4777 demand response mode requirements.

6.3.2.4 Load Balancing

Integrated three phase inverters must be used for PV systems connecting to three phase power supply unless micro-inverters are used.

PV systems connected to multiple phases must be balanced within 20A or to the approval of the DNSP. In addition, protection must be installed to isolate the inverter if the current imbalance is greater than 20A or where a voltage imbalance greater than 2% is detected.

6.3.2.5 Other requirement

DC connectors between the inverter and PV array DC input must be of the same manufacturer and model.

6.3.2.6 Warranty

The inverter must have a minimum warranty of 10 years.

6.3.3 MICRO-INVERTER REQUIREMENTS

Micro-inverters must meet all inverter requirements as listed above and all requirements set out by AS/NZS 5033 4.3.12 *Small micro-inverter installations.*

Systems with micro inverters must have AC isolators installed at the array. If the system is installed in multiple locations or spread over different roof surfaces then an AC isolator must be provided at each group of modules.

6.3.3.1 Cables and Connectors

AC cable and connectors connecting micro-inverters to the Electricity distribution board must be fit for purpose.

DC connectors between inverter and PV module(s) must be of the same manufacturer and model.

6.3.3.2 Fixings and Fasteners

Any fixings and fasteners used to secure the micro-inverters must be fit for purpose.

6.3.4 DC POWER OPTIMISER REQUIREMENTS

Power Optimiser units must comply with requirements set out by AS/NZS 5033 for strings constructed using DC conditioning units.

6.3.5 MOUNTING SYSTEM REQUIREMENTS

The mounting frame and associated parts, including but not limited to parts such as bolts, splices, etc. must be a suitable proprietary made product. Custom made products are not acceptable.

Raked mounting system should be used on roofs with less than 10 degree pitch.

The mounting system manufacturer's installation specification, including but not limited to: maximum fixing width for wind regions and roof zones, maximum building height and roof mounting requirements, must be followed.

6.3.5.1 Certification

The mounting system documentation must include engineering certification of the product's compliance with AS/NZS 1170.2. The manufacturer must provide installation methods that are compliant with AS/NZS 1170.2 for the terrain category and wind region applicable to the installation site.

6.3.5.2 Warranty

Minimum of:

5 years finish warranty
10 years product warranty

6.3.6 MONITORING SYSTEM REQUIREMENTS

The system must be integrated to the University's Advanced Utilities Monitoring System (AUMS) in accordance with the CIS Advanced Utilities Monitoring System Standard. The system monitoring must cover as a minimum;

1. Electrical meters at the distribution board
2. Inverter monitoring including;
    a. DC String voltages
    b. DC String currents
    c. DC Power
    d. AC voltage
    e. AC current
    f. AC power
    g. AC kVA
    h. AC power factor
    i. THD
    j. Earth fault detection and alarming

If weather monitoring is required, sensors and data logging for insolation (measured at array tilt) and PV cell temperature must be provided.

If energy storage is installed, monitoring and data logging of charging, discharging and state of charge must be provided.

All system monitoring data must be collectively recorded so that the entire system, including PV production, weather data and energy storage data, can be easily assessed.

6.3.7 BALANCE OF SYSTEM COMPONENT REQUIREMENTS

All balance of system components installed on the DC side of the system must be rated for DC application.

All equipment, including any conduit and ducting, exposed to the outdoor environment must be a minimum of IP55 compliant and must be UV resistant.

6.3.7.1 DC Cables

PV cables must comply with requirements set out by AS/NZS 5033.

Cable size must be selected such that the voltage drop from furthermost the PV module to the inverter is less than 3%.

All AC and DC wiring and components must be installed in separate enclosures and run in separate conduit.

6.3.7.2 DC isolators

DC isolators must be installed where required by AS/NZS 5033, and the isolators must meet the device requirements set out by AS/NZS 5033.

DC isolators should meet the following specifications:

- Type: Rotary type DC isolator;
- IP rating: IP66 or higher;
- Provide within specification sheet:
    - Single pole voltage and current rating
    - Wiring diagram

Isolator enclosures must be installed according to manufacturer's specifications to ensure IP rating is maintained.

DC isolator enclosures should be constructed of metal and equipotentially bonded to earth.
See *Attachment 5: DC Isolator Rating and Installation* for more information.

6.3.7.3 AC cable

AC cable between PV system inverter output and consumer mains must be selected such that:

- Voltage rise between inverter and main switchboard is less than 1% and,
- Voltage rise between main switchboard and consumer main is less than 1%.

6.3.7.4 AC circuit breaker

AC circuit breaker acting as the main switch (inverter supply) must be rated to protect the cable against overcurrent to *AS/NZS 3000*.

AC circuit breaker ratings must be above inverter maximum AC current output rating to avoid unnecessary tripping of circuit breaker. The cable between the inverter and the AC circuit breaker must have a higher current carrying capacity than the AC circuit breaker rating and the maximum AC current output of the inverter.

6.3.7.5 PV string protection

PV string overcurrent protection, if needed, must adhere to sizing and location requirements as set out by AS/NZS 5033.

Circuit breakers should not be used for string overcurrent protection.

6.3.7.6 Plugs, sockets and connectors

Plugs, sockets and connectors used in the PV system must comply with AS/NZS 5033.

Note: Plugs and sockets must only be mated with those of the same type from the same manufacturer. Mating of plugs and sockets that are compatible but do not meet the above criteria (e.g. mating of MC4 connectors with MC4 compatible connectors from another manufacturer) is not acceptable.

Ensure that PV modules and/or inverter warranty will not be voided in the event that pre-installed connectors need to be replaced. To avoid the need to replace pre-installed connectors it is recommended to only use PV modules and inverters for which matching connectors can be sourced.

6.4 SYSTEM INSTALLATION

PV system installation includes the installation of all PV system components, e.g. PV modules, inverters and balance of system components, as well as ancillary work such as forming openings in the building envelop for cable entries etc. The PV system provider must ensure that the integrity of the building, especially waterproofing and fireproofing properties, is not affected by the installation of the PV system.

All PV system components must be installed in a manner such that the manufacturers' product warranties are not affected.

6.4.1 ASSET LABELLING AND BAR CODING

Equipment must be provided with asset labels and bar codes as per CIS Asset Identification and Labelling Standard.

6.4.2 PV MODULE INSTALLATION

Installation of the PV modules onto the mounting system and attachment of mounting system equipment to the roof must follow the respective manufacturer's specifications for the specific application. See *Attachment 6: Installing PV Modules on Roof* for more information.

All equipment used must be fit for purpose and care is to be taken while installing so as to not adversely affect the system finish or void warranties.

Ensure that bolts, washers, screws, nails or other metal objects in contact with the mounting frame are of a similar metal to reduce the likelihood and severity of galvanic reaction. The use of stainless steel with aluminium frames is recommended. Where the use of dissimilar metals cannot be avoided insulating washers or similar must be used.

6.4.2.1 Module performance

PV modules must be installed such that all strings connected in parallel to the same MPPT input comprise the same number of panels and are of the same make and model.

A string of PV modules must be connected such that all modules in the string have the same tilt and the same orientation. This does not include micro-inverters and DC power optimisers connected to individual modules.

6.4.2.2 Mounting methods

PV array are installed avoiding edge zones as defined by *AS/NZS 1170.2 Wind Actions*.
All modules are installed with a minimum incline of 10° to ensure self-cleaning by rainfall.
For flush to roof type mounting, a distance of 60-100mm air gap should be provided between the rear of the PV modules and roof material.

For raked type mounting systems, sufficient space between rows of raked systems should be provided to ensure that shading to subsequent rows of modules is avoided between 9:00am and 3:00pm throughout the year.

6.4.2.3 PV module spacing

A gap should be provided between PV modules to allow for thermal expansion.

If excess roof space is available, large arrays should be installed as follows so that adequate access is provided for maintenance of the array:

- 500mm clearance around the perimeter of the PV array;
- For flush mounted arrays, every fourth row is spaced at least 700mm to provide a maintenance access way;
- Ensure that access to individual PV modules does not require the removal of more than one other PV module.

6.4.3 INVERTER INSTALLATION

The area surrounding the inverter and all associated protective devices such as PV array DC isolator, inverter AC isolators, and wiring must be known as the inverter station.

Inverter/s must be installed according to AS4777.1 requirements. In addition, where multiple inverters are installed connecting to the same switchboard, the inverters must be installed grouped in a common location. Each inverter must be provided with an AC isolation switch at an electrical distribution board. A main switch (inverter supply) must be provided to isolate all inverters installed on the distribution board.

6.4.3.1 Inverter station location selection

Inverter station location must have restricted access. Students or general public must not be able to gain unauthorised access.

Keying arrangements must be approved by the University Locksmith. To achieve this, the CIS Project Manager must log a service request to the CIS Lock Smith prior to installation to change over the project keys and lift bi-lock.

Inverters must be installed such that the ventilation and clearance requirements recommended by the inverter manufacturer are met.

The inverter station should be located and configured such that:

- No inverter is exposed to excessive heat, dust or moisture;
- No inverter is exposed to direct sunlight or rain;
- DC losses are minimised by locating the inverter as close as possible to the PV array;
- AC losses are minimised by locating the inverter as close as possible to the nearest electrical distribution board;
- Access to the inverter station components and cabling is restricted as described by AS/NZS 5033 regardless of system voltage.
- No flammable liquids or gasses must be stored at the inverter station location.

Inverter stations should be configured as outlined in *Attachment 7: Inverter Station Equipment Configuration.*

Refer to CIS Electrical Services Standard for additional connection requirements and restrictions.

6.4.4 CABLE MANAGEMENT/WIRING

Regardless of system voltage, the entire PV installation, including the PV array, inverters, associated wiring and protection, must have restricted access as described by AS/NZS 5033.

Conduits must be installed up to and including the cables at the inverter input. The conduits must be supported in such a way that it cannot be subjected to mechanical strain.

All DC cabling from the inverters to the PV array DC isolators adjacent to the array must be installed in metal or heavy duty (HD) conduit. This conduit must also be UV resistant (marked 'T'). The conduit must be labelled "Solar" every 2 metres, with the labelling clearly visible when installed. 'HD' and 'T' markings on the conduit should also be visible.

Cable installation must not be susceptible to damage by vermin or birds.
Cables must be installed to AS5033 and AS3000 requirements, in particular:

- Cables must not lay on roofs or floors without adequate enclosure;
- Plastic cable ties must not be used.
- DC connections must not be hanging under tension

Cables entering junction boxes must comply with *AS/NZS 5033*.
See *Attachment 5: DC Isolator Rating and Installation* for installation of cables through junction boxes and similar enclosures.

6.4.5 DC ISOLATORS

DC isolators must be installed to AS/NZS 5033 and manufacturer instructions.

See *Attachment 5: DC Isolator Rating and Installation* for further installation requirements.

6.4.6 ROOF PENETRATION BY PV SYSTEM

Roof penetrations must comply with CIS Roofing and Guttering Standard.
Any roof penetrations must be suitably sealed and waterproofed for the expected life of the system. Roof penetrations include cable entry and mounting system roof mounting points. In particular:

- For any horizontal roof penetration on a tiled roof, the installer must ensure that roof tile sits flat after installation. This may be achieved by grinding out the top and/or bottom of a roof tile to provide a flush fit of the mounting structure part to the tile;
- For any vertical roof penetration, purpose made roof flashing must be used to ensure a permanent seal. If silicone must be used as a sealant, a maintenance schedule should be included in the system maintenance to inspect and service the sealant over the life of the system;
- Silicone must not be used as a primary method of sealing roof penetrations or conduit ends. Instead, silicone should only be used to aid in the installation of purpose made products such as Dektites;
- Cable entry into conduit must face downwards and be appropriately sealed with a cable gland.

All cables at roof penetration should be enclosed in conduit or similar for protection against mechanical damage.

All roof penetrations for cabling must use a fit for purpose roof collar flashing (such as a Dektite). Collar flashing installed must have a minimum warranty of 15 years.

See *Attachment 8: Roof Penetrations.*

6.4.7 PV SYSTEM SIGNAGE

All PV system components must be labelled, as required by AS/NZS 5033 and AS 4777. Signs installed should be engraved plastic or metallic labels. In addition:

- Provide a plan view of PV system. The plan view should show the location of the PV modules, DC isolators, inverter, point of connection and data logger;
- Install a label "Do not switch off power supply" on power outlet for the PV monitoring devices;
- Label terminology must be identical to the terminology used in the system's shutdown procedure and other required documentation;
- A list of action/s to be taken if the earth fault alarm is activated should be placed next to the earth fault alarm and/or given to those who will receive earth fault notifications (the building's administration office or CIS); where the PV system contains multiple PV arrays and/or inverters, provide labelling on all isolators, inverters and arrays, identifying corresponding system components. For example, "Array - A" is connected to the rooftop "PV Array DC isolator - A", inverter "PV Array DC isolator - A", "Inverter - A" and so on.

See *Attachment 9: System Signage*.

6.4.8 LIGHTNING PROTECTION

The metal portions of photovoltaic array should be bonded to the existing lightning protection system if available as per AS/NZS 1768 and AS 3000.

6.4.8.1 Surge Protection Devices (SPD)

SPDs installed on the DC side of the PV system must be explicitly designed and manufactured for DC PV application.

Surge protection should be installed for each inverter. Surge protection to meet the following requirements:

- Connection type: shunt diverter
- Nominal voltage: > PV system operating DC voltage
- Maximum continuous voltage: 1000VDC
- Maximum continuous current rating: PV system short-circuit current
- Response time: < 5nS
- Maximum surge current (8/20µS): > 20kA
- Earth leakage current: <10µA

6.4.8.2 Minimising wiring loops

To reduce the magnitude of lightning-induced over voltages, the PV array wiring should be laid in such a way that the area of conductive loops is minimized. See AS/NZS 5033 for examples with minimum loop area.

6.4.9 EARTHING

All exposed conductive parts of the PV system, including PV module frame and mounting rails, must be bonded to earth (equipotential bonding) in accordance with AS/NZS 5033.

Both mounting rails on every row of PV modules must be bonded to earth.

The removal of any one module must not affect the bonding of the system. To ensure that bonding is maintained across rail joins, earthing straps must be installed across rail splices unless the manufacturer confirms (in documentation) that the splices maintain continuity.

Earthing lugs at the array must be sprayed with corrosion resistant paint.

6.4.10 SYSTEM WORKMANSHIP WARRANTY

The system provider must install the photovoltaic system to meet all relevant standards, building codes and local council requirements and in such a way that the manufacturers' warranties on all system equipment remains valid.

The System Provider should provide an installation workmanship warranty for a minimum of 5 years.

6.5 REMOVAL OF SYSTEM FOR REPAIR WORK

Where the PV modules are required to be removed to carry out renovation or repair work on the building, the removal and reinstall of PV modules must be carried out by CEC accredited installers.

Where individual PV modules need to be replaced, system documentation should be consulted to select replacement modules with electrical characteristics closest to the original PV module.

All system documentation should be updated to include date and details of any alterations or replacements made to the system equipment.

6.6 PV SYSTEM UPGRADES

The whole system must be brought up to standards applicable at the time of the upgrade.

If any additional PV strings are added to the system and these additions are PV modules of a different make or model to the original, the additional PV string/s should be installed and connected to an inverter's separate MPPT and within the input constraints of the inverter.

7 COMMISSIONING

After installation, the PV system must be commissioned according to AS/NZS 5033 as a minimum. Note that if the PV system has a rated capacity greater than 10kW, AS/NZS 5033 includes additional commissioning tests that must also be carried out.

At the completion of commissioning tests, the completed copy of the commissioning documents must be included in the system documentation provided to CIS.

See *Attachment 10: PV System Commissioning* for more information.

8 DEFECTS LIABILITY PERIOD

Unless stipulated otherwise under the project preliminaries, the defects liability period must be twelve months following practical completion of the system.

The following activities must be carried out during the Defects Liability Maintenance Period:

a. The system provider must provide a minimum of 12 months operations and maintenance service during the defect liability period. The scope of operations and maintenance activities will be as defined in Section 10 - Operations and Maintenance.
b. Thermo-graphic inspections of switchboards;

c. Fault rectification and replacement of faulty materials, equipment and accessories with new;
d. Prompt emergency response when required.

AT THE END OF THE MAINTENANCE PERIOD, CONTRACTORS MUST MAKE A FINAL SERVICE VISIT TO CERTIFY THE INSTALLATION IS OPERATING CORRECTLY. CIS STAFF TO SIGN OFF ON ALL SITE MAINTENANCE DOCUMENTS FOR ALL SITE VISITS.

9 DOCUMENTATION & RECORDS

Site-specific system documentation must be provided as outlined by AS/NZS 5033 and AS4777.1. Attachment 1: Documentation Checklist outlines specific requirements for drawings.

9.1 Design Submission

The following design documents must be provided:

1. Return Brief defining the systems proposed and any deviations from this specification;
2. System sizing calculations and performance estimate. This must be accompanied by a completed copy of Attachment 3: System sizing checklist
3. Budget calculations;
4. Recycling requirements of PV modules and batteries where applicable
5. Design drawings including as a minimum;
    a. A plan view of the PV array identifying key features
    b. Single line diagram/s
    c. Earthing diagram
    d. Metering and monitoring diagrams
    e. Structural drawings
6. Applications to Supply Authorities, and their responses;
7. Designers statutory compliance certificates;
8. Requests for all variations to this Standard submitted using the **CIS Request for Dispensation Form (CIS-ENG-F001);**
9. Complete the Design & Construct checklist using the **CIS Design & Construct Photovoltaic Services Checklist Form (CIS-ENG-F009).**

9.2 Commissioning Documentation

The contractor must submit the commissioning documentation identified in Attachment 10: PV System Commissioning.

System provider must keep the PV system installation information for a minimum period of 5 years including installation and commissioning photographs. The contractor must also submit photographs l showing:

1. The position of the PV array relative to the building on which it is installed;
2. Mounting and external cabling;
3. Inverter station layout;
4. Key equipment, such as, isolators, junction boxes and system protection;
5. Electricity board showing inverter system isolation switches and relevant signage;
6. Meter switchover (where applicable).

9.3 Practical Completion

1. The system provider must explain to CIS the operation and maintenance requirements of the PV system components upon completion.
2. The system provider must demonstrate the monitoring systems installed

3. The system provider must submit the Operation and maintenance manual including the items listed in Attachment 1: Documentation Checklist

4. The system provider must submit the As built drawings including the items listed in Attachment 1: Documentation Checklist, as a minimum;
   a. A plan view of the PV array identifying key features
   b. Single line diagram/s
   c. Earthing diagram
   d. Metering and monitoring diagrams
   e. Structural drawings

10 OPERATIONS AND MAINTENANCE

Maintenance procedure and timetable must follow the recommendations of AS/NZS 5033.

Items shown as part of the maintenance procedures must be performed on a scheduled basis as specified and must be carried out by a CEC accredited solar electrician.

All maintenance actions performed on the PV system must be clearly documented in the maintenance timetable.

An example Maintenance procedure and timetable has been provided in *Attachment 11: PV System Maintenance*. This is to be used if the procedure provided by the system provider is not available.

11 AUTHORISATION OF VARIATIONS

CIS Engineering & Sustainability Unit must authorise any proposed variations or departures from this standard.

12 QUALITY CONTROL

Minimum compliance requirements of this design standard are specified in Attachment 1. They are specified for the following stages:

- Design and documentation
- Tender
- Construction
- Defects Liability

Project managers, consultants and commissioning agents must ensure compliance with these requirements is achieved. Formal sign-off from standard's author or delegated authority from the business unit/division is required for acceptance of any non-compliances and departures from the standard's requirements.

13 REFERENCES

As per section *6.1* Compliance with Australian Standards and Guidelines

14 NOTES

N/A

15 ATTACHMENTS

- Attachment 1: Documentation Checklist
- Attachment 2: PV array tilt and orientation
- Attachment 3: System sizing
- Attachment 4: Array and Inverter Matching
- Attachment 5: DC isolator rating and installation
- Attachment 6: Installing PV modules on roof
- Attachment 7: Inverter station equipment configuration
- Attachment 8: Roof Penetrations
- Attachment 9: System Signage
- Attachment 10: PV System Commissioning
- Attachment 11: PV System Maintenance

15.1 ATTACHMENT 1: DOCUMENTATION CHECKLIST

Drawings:

1. A plan view of the PV array, clearly showing:
   a) How the PV array is wired;
   b) Access routes (as relevant);
   c) Electrical reticulation;
   d) Penetration points;
   e) Module identifier number (corresponding to serial numbers on the asset schedule);
   f) Tilt angle
   g) Location of key system equipment and switches.
2. Single line diagram/s, in accordance with the CIS Electrical Standard showing;
   a) connection of all PV system equipment to electrical distribution board, including the electrical ratings of the PV array and electrical ratings of all overcurrent devices, isolators and switches
   b) A table nominating which strings are connected to which inverter, by both inverter number and inverter input (A/B);
   c) Indicate total number of panels and installed capacity on title block;
   d) Lightning protection system (if required);
   e) String configuration back to the inverters. String configuration is to be identified using hatching or colour and string number to distinguish strings;
   f) Location and rating of DC isolation points and the strings connected;
   g) DC string fuses including rating (if required);
   h) Surge diverters;
   i) Cable size;
   j) Identifying AC connection point (DB name/number) and breaker size;
   k) Inverter schedule;
   l) Indicating type and number of panels connected to each inverter;
   m) Array Voc;
   n) Array Isc;
   o) Inverter maximum AC current rating;
   p) Panel Voc;
   q) Panel Isc;
   r) Secondary protection devices;
3. Earthing diagram
4. Metering and monitoring drawings:
   a) Power;
   b) Communications;
5. Structural drawings:
   c) Mounting system drawings and details as required;
   d) Details of any structures that tie into the building fabric. e.g. structural plinths.

Operation and Maintenance Manual, including:

1. A description of the function and operation of the system's installed equipment;
2. A procedure to verify the correct operation of the system;
3. The supplier's contact details for installation queries and system support;
4. The shutdown and isolation procedure for emergency and maintenance, including any electrical safety warnings;
5. A list of equipment supplied, with serial numbers of all equipment where applicable;
6. A list of actions to be taken in the event of an earth fault alarm;
7. A site specific system performance estimate providing monthly generation estimates taking into account expected seasonal, operational and site specific variation. The system performance estimate should at a minimum factor in effects of the PV array orientation, shading effects and

de-rating factors such as temperature and equipment efficiency. Any assumptions made must be clearly stated.

8. Array frame engineering certificate for wind and mechanical loading;
9. Installer/designer's declaration of compliance to AS/NZS 5033:2014 2.2 *Mechanical design*;
10. Warranty information for all applicable equipment and workmanship warranties;
11. Network Provider's PV system approval to connect and connection offer;
12. Equipment manufacturer's documentation and handbooks for all equipment supplied. As a minimum the following must be included:
    - Panels;
    - Mounting frame;
    - Inverter;
    - Isolators;
    - Cable;
    - Monitoring devices.
13. Log-in details for any monitoring systems
14. The commissioning sheet and installation checklist;
15. Maintenance procedure and timetable

15.2 ATTACHMENT 2: PV ARRAY TILT AND ORIENTATION

The tilt and orientation of PV modules must be optimised to maximise PV system power generation. Typically, PV modules are optimally placed to achieve the highest year round generation when their inclination is approximately equal to the angle of latitude and facing true north.

EFFECTS OF EAST AND WEST FACING ARRAYS

PV arrays installed on an easterly or westerly aspect will have vastly reduced power production during evenings and mornings respectively. However, east and/or west facing arrays can provide an alternative system design when there are no suitable spaces for north facing arrays.
Consider:

- Are there any geographic features or prevalent weather patterns which reduce PV generation, and can they be avoided by orienting the arrays differently?
- Are there any objects or shading on north, east of west facing roofs, making them unsuitable for PV systems?
- Does the site have high morning or afternoon loads that can be offset by PV generation?

EFFECT OF TILT AND ORIENTATION ON PV GENERATION

Any proposed PV system must include site specific system energy yield estimates and system costing. Irradiation data used to calculate power production must be site specific and take into account the effect of array tilt and orientation. Figure A2 below shows an example of multipliers to apply to horizontal irradiation data to calculate site specific PV generation.

Sydney
during January

Plane Azimuth (degrees)	Plane Inclination (degrees) 0	10	20	30	40
270	100%	100%	99%	96%	92%
280	100%	100%	99%	97%	93%
290	100%	100%	100%	97%	93%
300	100%	101%	100%	97%	93%
310	100%	101%	100%	97%	93%
320	100%	101%	100%	97%	92%
330	100%	101%	100%	97%	92%
340	100%	101%	100%	97%	91%
350	100%	101%	100%	96%	91%
0	100%	101%	100%	96%	90%
10	100%	101%	100%	96%	91%
20	100%	101%	100%	96%	91%
30	100%	101%	100%	97%	92%
40	100%	101%	100%	97%	92%
50	100%	101%	100%	97%	92%
60	100%	100%	100%	97%	92%
70	100%	100%	99%	96%	92%
80	100%	100%	99%	96%	92%
90	100%	100%	98%	96%	91%

Sydney
during June

Plane Azimuth (degrees)	Plane Inclination (degrees) 0	10	20	30	40
270	100%	101%	101%	101%	100%
280	100%	105%	109%	111%	111%
290	100%	109%	115%	120%	123%
300	100%	112%	122%	130%	134%
310	100%	115%	128%	138%	145%
320	100%	118%	134%	146%	156%
330	100%	121%	138%	154%	164%
340	100%	122%	142%	159%	170%
350	100%	123%	144%	162%	174%
0	100%	124%	144%	163%	176%
10	100%	123%	144%	162%	175%
20	100%	122%	142%	159%	171%
30	100%	121%	139%	154%	165%
40	100%	118%	134%	147%	156%
50	100%	116%	129%	139%	146%
60	100%	112%	123%	131%	135%
70	100%	109%	116%	121%	124%
80	100%	105%	109%	111%	112%
90	100%	101%	102%	102%	100%

Figure A2. Data table of daily irradiation of Sydney on an inclined plane expressed as percentage of the horizontal value for the months of January and June (CEC, 2013). The plane azimuth indicates the module orientation, and the plane inclination indicates module tilt angle.

MODULAR PV ARRAY SOLUTIONS

System providers may propose PV systems that use micro-inverters (also known as AC systems) or DC Power optimisers. PV systems installed with micro-inverters or DC power optimisers can have higher PV generation when compared to a conventional PV system due to their ability to optimise individual PV module generation and mitigate loss aggregation.

PV systems that utilise this type of equipment do not require all modules in the PV array to have the same tilt and orientation. However, PV modules in these systems should still be oriented and tilted as previously outlined to maximise system output.

15.3 Attachment 3: System sizing checklist

An example checklist is provided below as a guide for preliminary system sizing evaluation.

	Question	Yes	No
1 Load requirement calculation			
1.1)	Load requirement calculation uses electricity usage data	☐	☐
1.2)	Load requirement calculation accounting for seasonal variation	☐	☐
1.2)	Load requirement calculation accounting for weekday/weekend variation	☐	☐
1.3)	Investigate energy efficiency measures to reduce load requirement	☐	☐
2 PV generation estimate			
2.1)	Site specific solar insolation data is used	☐	☐
2.2)	Solar insolation data used has been adjusted for PV array tilt and orientation	☐	☐
2.3)	Performed shade analysis: shading effects has been factored	☐	☐
2.4)	Array physical size has been checked against available space	☐	☐
2.5)	Annual PV generation estimate is provided	☐	☐
2.6)	Annual PV generation estimate does not exceed onsite energy consumption	☐	☐
2.7)	PV generation degradation estimate is provided	☐	☐
2.8)	PV generation estimate accounts for system losses	☐	☐
2.9)	Assumptions used to calculate PV generation estimate is provided	☐	☐
2 Electricity offset calculation			
2.2)	Energy saving calculation is provided	☐	☐
2.3)	Energy saving calculation accounts for time of use tariff (where applicable)	☐	☐
2.3)	Energy saving calculation accounts for electricity tariff changes	☐	☐
2.4)	Energy saving calculation accounts for PV generation degradation and maintenance costs	☐	☐
3 Final outcomes			
3.1)	System size and resultant cost are acceptable	☐	☐
3.2)	Proposed system installation area is practical	☐	☐
3.3)	PV system return on investment rate is acceptable	☐	☐

15.4 ATTACHMENT 4: ARRAY AND INVERTER MATCHING

Inverters have a set range of PV array input voltage and current values within which the inverter can operate safely and efficiently. Matching the array and inverter correctly will reduce the chance of inverter failure and ensure that the system generates the expected energy yield.
It is the PV system designer's responsibility to ensure that the PV array's electrical output lies within the inverter's operating parameters.

As a guide, the capacity rating of a PV array connecting to an inverter should match the inverter's nominal AC power rating. The PV array capacity rating should be greater than 95% of the inverter's nominal AC power rating to ensure that the PV array's electrical characteristics do not easily fall below the inverter's operating window. For example, if an inverter with a nominal AC power rating of 5kW is used, the PV array's capacity rating should not be lower than 5kW x 95%, or 4.75kWp.

Oversizing of array is allowed provided that the inverter manufacturer has given written assurance that the inverter is suitable for use in this way and the warranty will not be voided with this application.

Oversizing of array describes the connecting of the inverter to a PV array that has a capacity rating greater than the inverter's DC input power rating. By oversizing the array, the PV system will produce more power in the morning and evening, and other times of low solar irradiation. Conversely, when solar conditions are favourable, the PV array's output is 'clipped' and the potential energy from the system is lost. This behaviour is demonstrated in Figure A4 below.

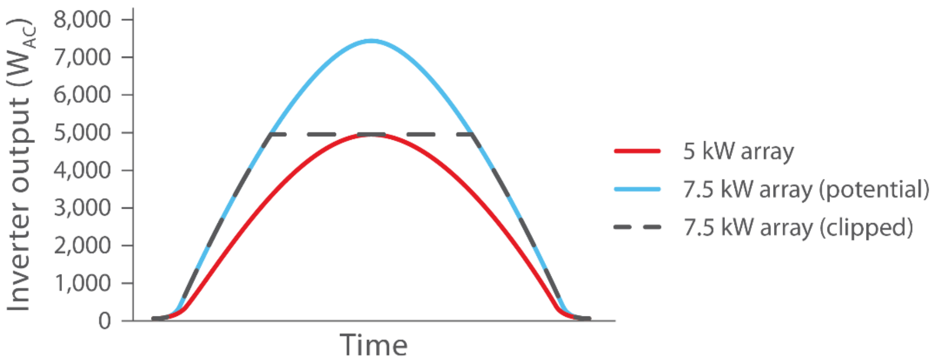


Figure A4. Clipping effect when a 5kW inverter is connected to a 7.5kWp array. The area above the 5kW line represents energy that is not collected by the inverter

Due to the lower cost of PV modules relative to inverters, effective oversizing of the array ensures the value of obtaining more energy per inverter is greater than the value of the potential energy that is not collected.

The CEC's *Grid Connected Solar PV systems – Design guidelines for accredited installers* requires the inverter rating to be at least 75% of the PV array capacity rating. For example, if an inverter with a nominal AC power rating of 5kW is used, the maximum PV array size would be 5kW ÷ 75%, i.e. 6.65kWp.

	System 1	System 2	System 3	System 4
Proposed array capacity (W_p)	4250	5000	6000	6250
Inverter rated DC power input (W)	5250	5250	5250	5250
Inverter rated AC power output (W)	4600	4600	4600	4600
Inverter rated DC power input greater than array capacity	YES	YES	NO	NO
Array capacity greater than 95% of inverter AC power	NO	YES	YES	YES
Inverter AC power output rating larger than 75% of array capacity	YES	YES	YES	NO

Table A4. Example matching of different sized arrays to a 4.6kW inverter

Table A4 shows four different systems matched to a 4.6kW inverter. Inverter and array are appropriately matched where array capacity is greater than 95% of inverter AC power and inverter AC power output rating is larger than 75% of array capacity.

System 2 and system 3 are acceptable system configurations, where system 3 has an oversized array within the acceptable range. System 1 should consider using an inverter with a lower power rating, and system 4 should consider using an inverter with a higher power rating.

It is of critical importance that care is taken to ensure that the PV array's electrical characteristics are within the inverter's allowable array size specifications.

15.5 Attachment 5: DC isolator rating and installation

The follow procedure must be used when selecting and installing load breaking DC isolators for PV systems.

DC Isolator Sizing Requirements

If sufficient information is provided by the manufacturer, temperature derating must be accounted for when assessing isolator ratings. Where possible, temperature derating at 80°C must be applied.
The DC isolator's voltage rating must be above the required voltage rating. Depending on the PV installation characteristics, PV Array DC isolators at the inverter and the array are to be rated to the PV array maximum voltage, either for each positive and negative conductor individually (a per pole voltage rating) or, less commonly, for both positive and negative conductors collectively (an overall voltage rating).

The DC isolator's current rating must be above the required current rating. In most cases the required current will be 1.25 x the short circuit current (I_{SC}), however AS/NZS 5033:2014 Table 4.2 must be used to confirm the required current rating.

Array configuration	Non-isolated PV system*	Isolated PV system†
Voltage	Isolator is rated to PV array maximum voltage for each conductor individually	Isolator is rated to PV array maximum voltage for both conductors collectively
Current	$I_{SC} \times 1.25$§	

Table A5.1: Required load breaking DC isolator ratings.

*A non-isolated PV system is a system that has a transformerless inverter.

†An isolated PV system is a system using a transformer inverter.

§Applicable for the majority of systems, but not all. See AS/NZS 5033:2014 Table 4.2 for more information.

NOTE: Systems with functional earthing require the same isolator ratings as non-isolated PV systems.

To calculate the PV array maximum voltage, multiply the PV array open circuit voltage (V_{OC}) by the appropriate correction factor in the following table from AS/NZS 5033:2014 Table 4.1. Use the lowest expected ambient temperature for the installation location as the lowest expected operating temperature.

VOLTAGE CORRECTION FACTORS FOR CRYSTALLINE AND MULTI-CRYSTALLINE SILICON PV MODULES

Lowest expected operating temperature °C	Correction factor
24 to 20	1.02
19 to 15	1.04
14 to 10	1.06
9 to 5	1.08
4 to 0	1.10
−1 to −5	1.12
−6 to −10	1.14
−11 to −15	1.16
−16 to −20	1.18
−21 to −25	1.20
−26 to −30	1.21
−31 to −35	1.23
−36 to −40	1.25

Table A5.2: Voltage correction factors for calculating the PV array maximum voltage. AS/NZS 5033:2014 Table 4.1

DC ISOLATOR INSTALLATION REQUIREMENTS

Installing load breaking DC isolators adjacent to the array is a requirement under AS/NZS 5033. In addition to this, load breaking DC isolators are also required at the inverter unless the inverter is within 3 metres of the array and visible from the array. This standard specifies that the IP rating must be a minimum of IP66 and enclosures should be constructed of metal and equipotentially bonded to earth. Furthermore, enclosures must be installed to the manufacturer's instructions to maintain their IP rating.

Installation of DC isolator enclosures must comply with AS/NZS 5033.

Unless otherwise specified by the manufacturer the following installation methods must be followed.

- Enclosures must be readily available as defined by AS/NZS 5033.
- Enclosures should be mounted so that it is standing upright or lying on its side according to AS/NZS 5033 unless otherwise specified by the manufacturer.
- Penetrations should be made at the lowest point of the enclosure. This includes: cable entries, conduit entries and screw holes;
- Enclosure openings/lids should not be upwards facing;
- Any penetrations made during installation, such as for screwing the enclosure to the mounting rail, should be waterproofed using an appropriate gland or gasket;
- Enclosures should not shade the array. If some shading is unavoidable, there should be no shading between 9am and 3pm;
- All conduit entries and connections must be glued unless not required by the manufacturer;
- Any cable glands used must be appropriate for the number of cables installed. Single cable glands used for multiple cables is not acceptable;
- All unused cable entry bungs or caps should be tightened and if no gasket is provided then they should be glued or adequately sealed with silicone;
- Ensure enclosure openings/lids are not obstructed by module frames or other objects and can open fully;
- Mounting holes provided by the manufacturer must be used to mount the enclosure. Where applicable caps/pips will be used to seal the screws. Any screws inside the enclosure that are not covered with a cap/pip will be covered with silicone to provide galvanic insulation.
- A shroud must be installed over all DC isolators that are exposed to direct sun or rain.

Figure A5: Shroud installed over rooftop isolator at the array

15.6 Attachment 6: Installing PV modules on roof

Manufacturers' installation instructions must be followed to ensure secure installation of the PV system to last the expected lifetime of the system. It should also be noted that manufacturers' ratings and compliance to certain standards will only be achieved by installing PV systems to manufacturers' specifications.

PV module attachment to rail

A PV module's ability to withstand wind and static load is affected by the attachment area. Manufacturers will specify the clamping area of the module. Clamping of PV modules onto rails must fall within the modules' specified clamping area to ensure that the modules can withstand loads up to the rated pressure.

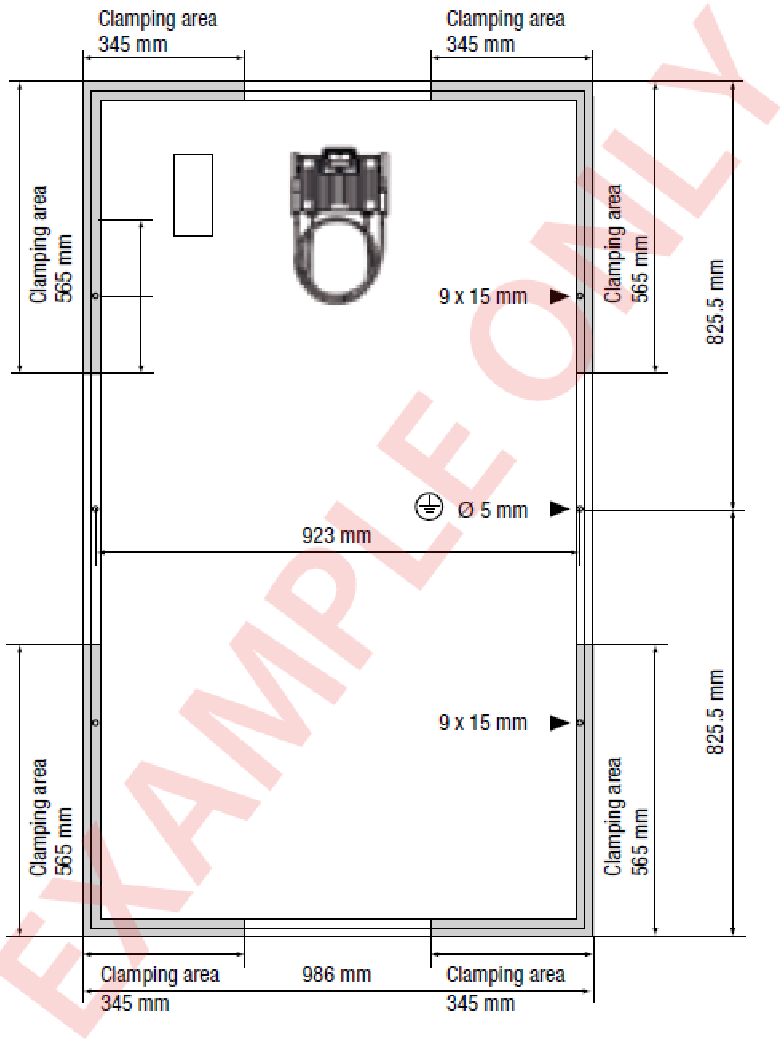


Figure A6. PV module clamping zone example: Module dimensions of Conergy PowerPlus 245M-260M modules showing clamping area in grey.

MOUNTING SYSTEM ATTACHMENT TO ROOF

Mounting systems will only be compliant to AS/NZS1170.2 if the manufacturer has supplied installation instructions certified to AS/NZS1170.2 and these instructions are followed. Care must be taken to ensure the manufacturer's installation requirements for the specific wind region and terrain category are met, especially:

- Maximum allowed rail end overhang;
- Maximum rail support spacing;
- Extra rail support spacing requirement in roof edge zones;
- Method of installing fixings to roof, such as screw type, gauge and quantity per fixing point.

10°-20° pitch

Wind Region	Building Height – H (m)		
	H≤10	10<H≤15	15<H≤20
A	**1476**	**1253**	**1105**
B	**1025**	**877**	**777**
C	**655**	**563**	**501**
D	**418**	**361**	**322**

20°-30° pitch

Wind Region	Building Height – H (m)		
	H≤10	10<H≤15	15<H≤20
A	**1589**	**1366**	**1203**
B	**1115**	**952**	**843**
C	**710**	**610**	**543**
D	**452**	**390**	**348**

Table A6. Mounting system installation specification example: Clenergy ezRack mounting system installation manual extract showing maximum rail support spacing for tile roofs in terrain category 3

If an installation configuration is not covered by the mounting system manufacturer's specification, a structural engineer's certificate must be obtained for the proposed installation configuration, stating the compliance of the proposed installation method with AS/NZS1170.2.

Manufacturer's installation instructions and corresponding engineer's certificate must be provided as part of the system documentation.

If a ballast system is to be installed, signed engineering certification must be obtained: both for the roof's ability to support the ballast system and array components; and for the ballast requirements to adequately secure the array.

15.7 Attachment 7: Inverter station equipment configuration

Inverter station refers to the area where one or more inverters and related equipment are installed. An inverter station is typically located near an electrical distribution cupboard to reduce losses, but can be installed in a designated space within a 1% AC voltage rise margin, and where inverters are protected from exposure to excessive heat, dust and moisture.

Installing inverter station equipment in a clear and logical way can ensure segregation of AC and DC electrical systems and ease of operation for maintenance or safety reasons.

Inverter station equipment installation requirement

Inverter station equipment includes the following:

- PV system inverter/s;
- PV array DC isolator/s and isolator enclosure/s;
- Inverter AC isolator/s and isolator enclosure/s;
- AC and DC cables connected to the inverter and cable enclosure;
- Any electrical switchboard adjacent to inverters.

Inverter station equipment must be installed meeting manufacturers' specified minimum clearance to maintain inverter efficiency and rated lifetime. Where objects are installed within the clearance zone, system owners must be made aware of the effects of having reduced clearance around inverters and an inverter manufacturer declaration, stating that this installation configuration is permitted, must be included in the system documentation.

Conduits enclosing PV array DC cables must be installed to AS5033 requirements.

Cables leading up to the inverter must be secured by saddles so they cannot be inadvertently unplugged from the inverter.

Cable penetration through walls into isolator enclosures must be sealed to AS3000 requirements to prevent the spread of fire.

Where multiple inverters are installed at the inverter station, an AC isolator must be provided for each inverter. Additionally, a single AC isolator should be provided for isolation of all inverters connected to the same electrical distribution cupboard.

Equipment arrangement

Equipment at the inverter station should be arranged as follows:

- Provide AC isolators at the inverters if the inverters are not within 3 metres and in line of sight of switchboard to which they are directly connected;
- Install all switching devices and inverters no lower than 0.5 metres and no more than 2.0 metres above the ground, floor or platform;
- Allow a minimum of 0.6 metres access clearance in front of all switching devices and inverters;

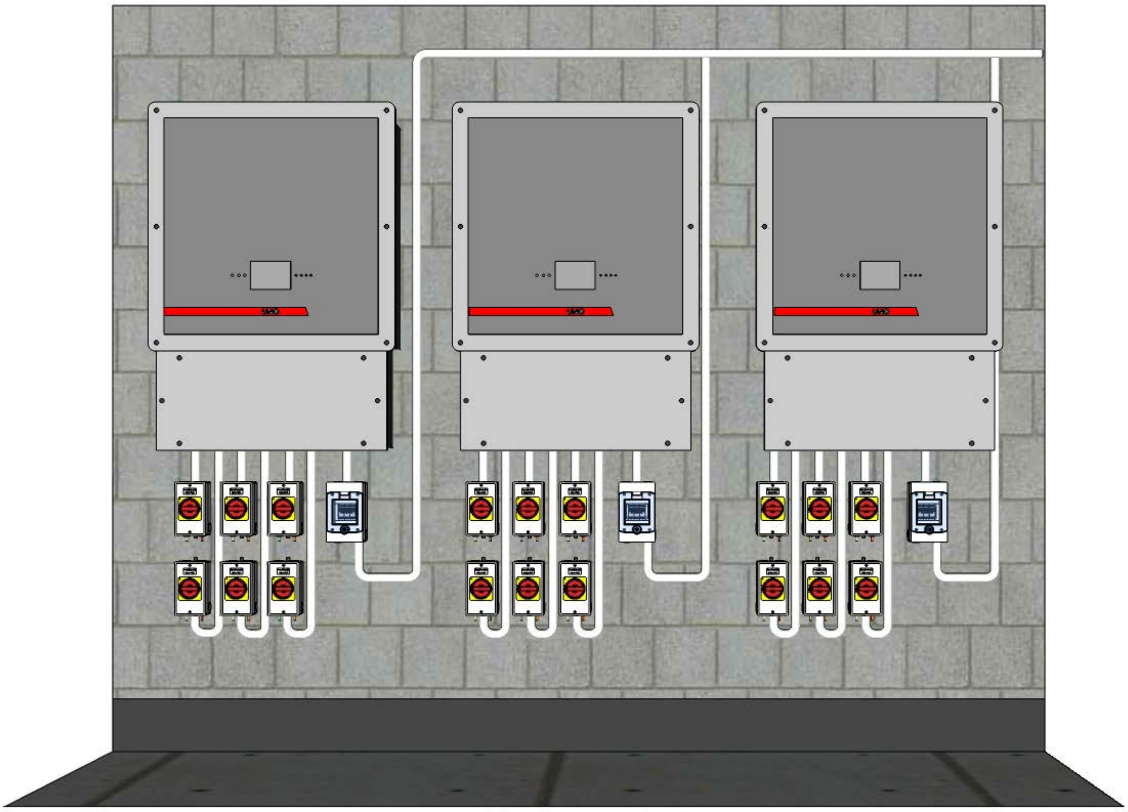


Figure A7. Example configuration of an inverter station. In this example, DC cables enter isolator enclosures from the wall cavity (NOTE: Some inverters may have AC and DC inputs arranged differently to those pictured. The arrangement of protective devices and cable should be adjusted for the location of those inputs)

15.8 ATTACHMENT 8: ROOF PENETRATIONS

Installation of PV modules on roofs often requires penetration of the roof envelope for securing the mounting system and for facilitating cable entry. These points of roof penetrations create a potential for water ingress into buildings and electrical systems when they are not correctly installed, which can cause damage to property or a fire hazard. Care must be taken to ensure that roof penetrations are installed correctly to prevent water ingress.

Roof penetration can be classified into two main categories, horizontal penetrations and vertical penetrations. Both categories have their own characteristics and sealing requirement.

VERTICAL PENETRATION THROUGH ROOF

Vertical penetrations are made perpendicular to the roofing material. This method is required for metal roofs to facilitate cable entry and mounting foot fixings. Penetrations of cables into tiled roofs are also required to be vertical penetration.

Purpose made flashing and gaskets should be used on vertical penetrations, installed to manufacturer's specifications.

Where silicone sealants are used, ensure that checking of silicone seals have been included in the maintenance schedule in the system documentation.

HORIZONTAL PENETRATION THROUGH ROOF

Horizontal penetrations run through an existing gap between two materials, most commonly between two tiles. This is typically required by tile mounting systems for attaching tile feet to the roof. This penetration method must not be used for the wiring system penetration.

The mounting system must use purpose made tile feet designed for installation via horizontal penetration. Ensure the chosen tile hook is appropriate for the roofing material.

Where allowed by the roof material, grind out top and/or bottom of tiles where needed, to ensure tiles surrounding roof penetrations sit flat. Tile feet must not affect the way roof tiles sit. On brittle tiles, where grinding of tiles is not appropriate, large flashing or tile replacements should be used instead of conventional horizontal penetration methods.

Figure A8.1. Left: incorrectly installed tile hook without grinding tile. Right: correctly installed tile hook with ground tile so that the tiles can lay flat.

Figure A8.2. Left: wiring system penetration incorrectly installed between tiles. Right: wiring system penetration correctly installed with vertical penetration using a collar flashing.

CABLE ENTRY INTO CONDUIT

Poorly installed conduit at the roof can allow water to enter the conduit at cable entry points or connection points. This can lead to critical failure of the system via water ingress into switch gear or water damage at cable junctions.

Conduit at rooftop must be installed such that:

- Cable entry into conduit is installed with suitable glands to prevent water ingress;
- Cable entry into conduit faces downwards;
- Conduit joiners and adaptors are glued to prevent water ingress and conduits coming loose.

15.9 Attachment 9: System Signage

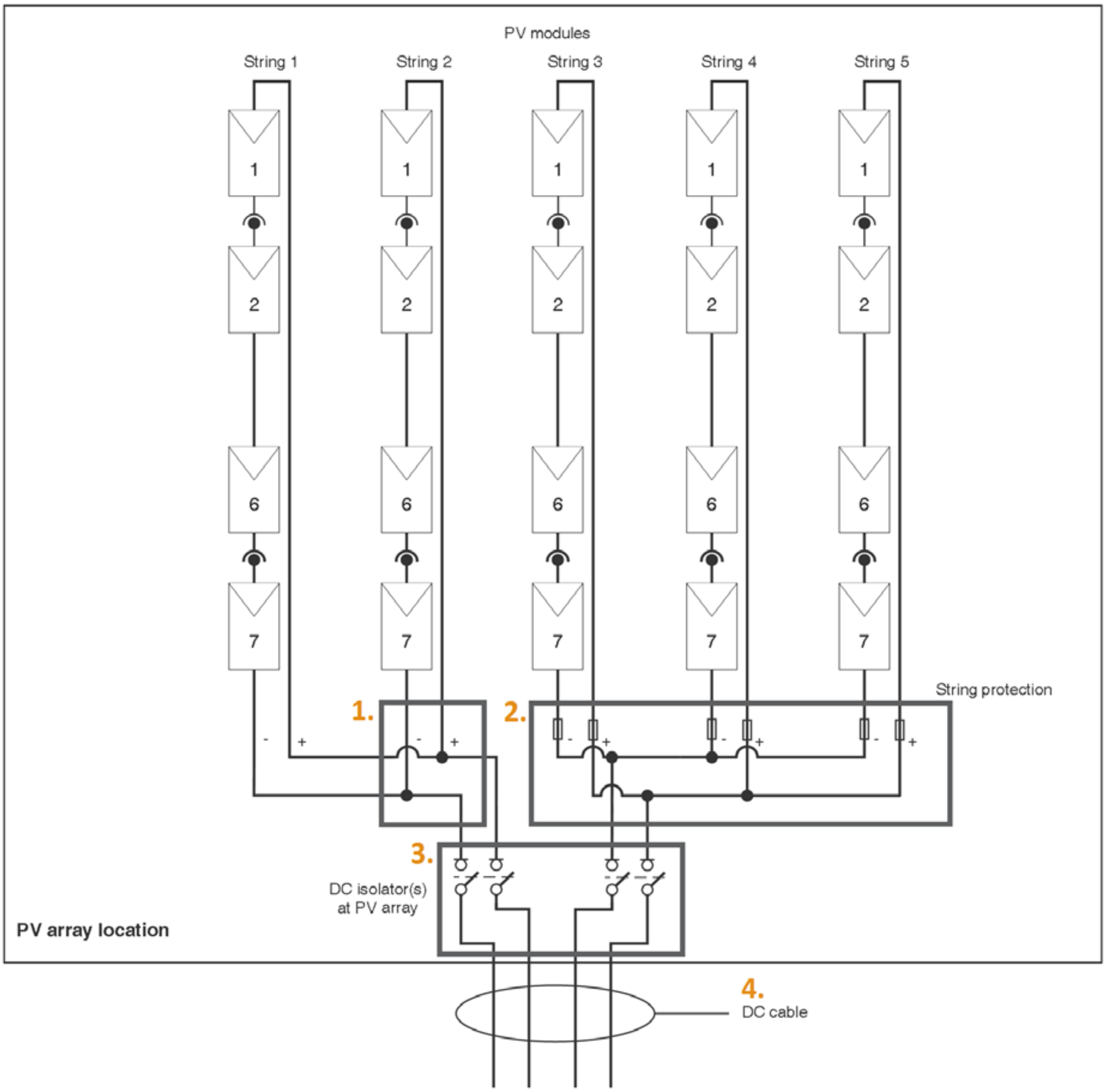
There is a range of PV system specific signage required according to Australian standards AS 4777.1 *Grid connection of energy systems via inverters* and AS/NZS 5033 *Installation and safety requirements for PV arrays*. Signage requirements can change when these standards are superseded so installers must ensure they follow the current standards.

Signs are installed to warn emergency crews and tradespeople of the presence of a PV system. Correct signage is required to convey certain system information, to warn of potential electrical danger, and to provide the correct procedure for switching the system off.

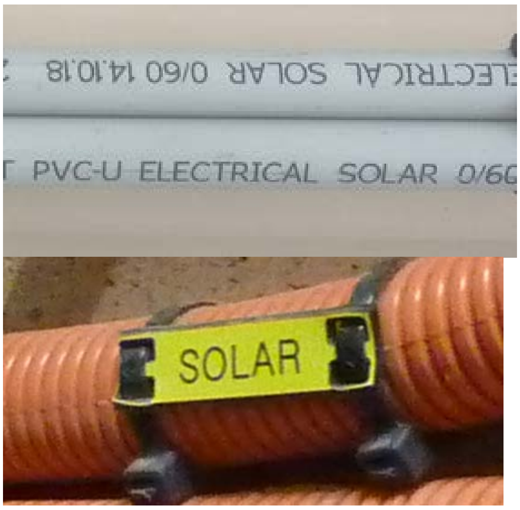
The sections below provide an overview of where and what signs are required by Australian standards for a typical grid connect system. The information is not exhaustive and is provided as guidance only; signage requirements for individual sites will differ due to system specific variations including, but not limited to: system configuration, system voltage, equipment used, equipment location, and existing switchboard layouts.

Note that labelling may visually differ from the examples shown. However, this is acceptable if the labelling complies with current standards and all additional requirements outlined by CIS.

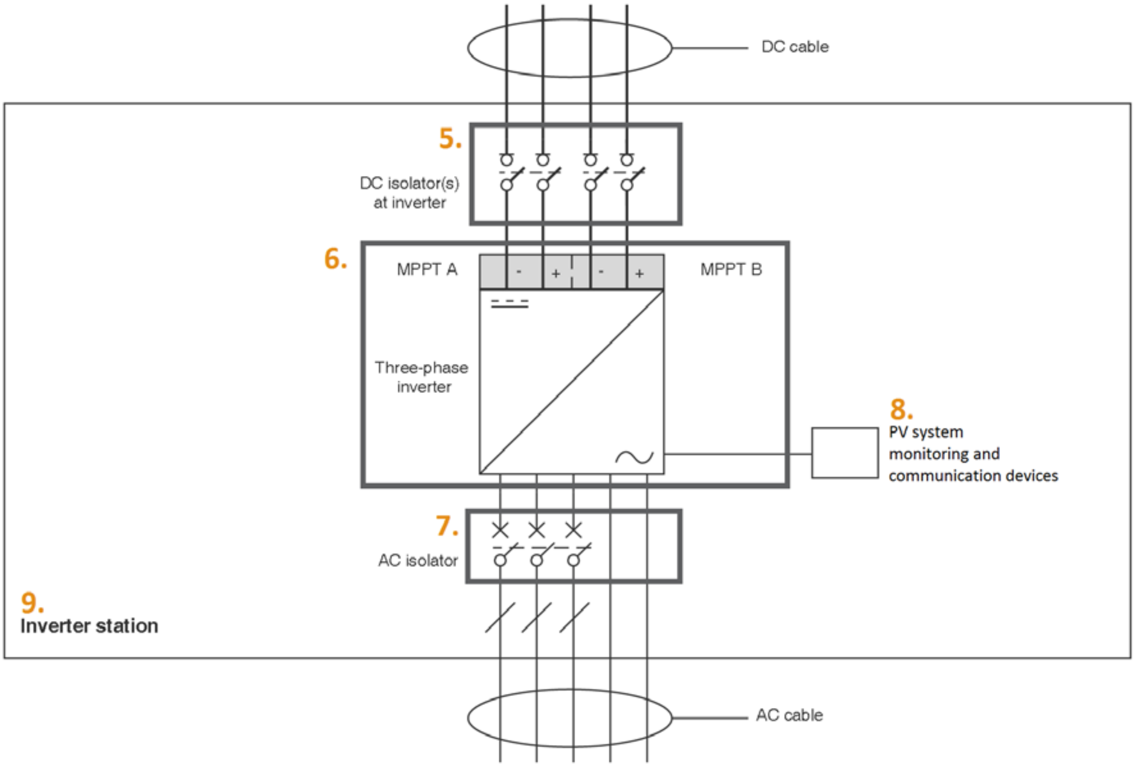
LABELLING AT THE PV ARRAY



Location	Labelling Requirement	Label example
1. PV array and PV string junction box	All PV array and PV array string junction boxes labelled "WARNING: HAZADOUS DC VOLTAGE" Black on yellow background	
2. String protection combiner box	Combiner box enclosure containing fuses labelled "Do not withdraw fuse under load"	DO NOT WITHDRAW FUSE UNDER LOAD

3. DC isolator enclosure adjacent to array	DC isolator enclosure labelled “PV ARRAY D.C. ISOLATOR”	
4. DC cables connecting array and inverter	Wiring enclosure labelled “SOLAR” every 2 metres and visible after mounting	

LABELLING AT INVERTER STATION

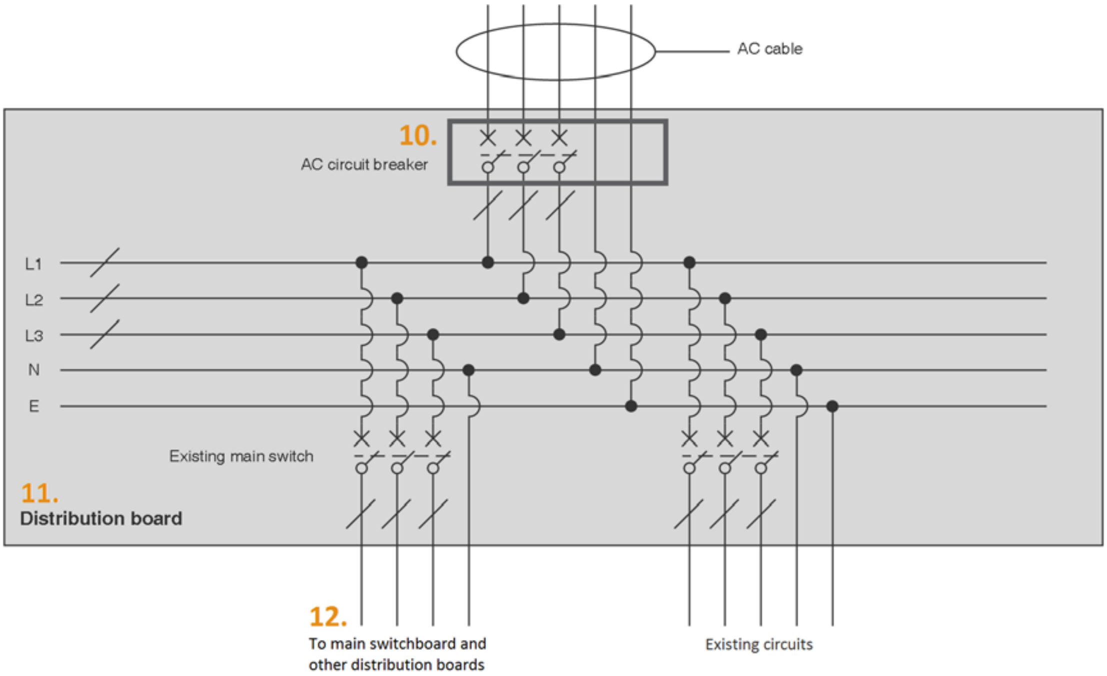


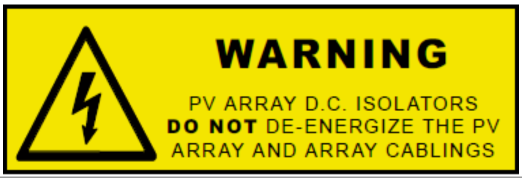
Location	Labelling Requirement	Label example
5. DC isolator enclosure at inverter	Enclosure labelled "PV ARRAY D.C. ISOLATOR"	**PV ARRAY DC ISOLATOR**
6. Inverter	Shutdown procedure Ensure that the descriptions in the procedure match the labels on the isolators to which they are referring.	SHUTDOWN PROCEDURE 1. Turn off the switch labelled 'inverter AC Isolator' located next to the AC terminals of the inverter 2. Turn off the switch labelled 'PV Array DC Isolator' located next to the DC terminals of the inverter **WARNING**: DO NOT OPEN PLUG AND SOCKET CONNECTORS OR PV STRING ISOLATORS UNDER LOAD PV ARRAY OPEN CIRCUIT VOLTAGE: V_{DC} PV ARRAY SHORT CIRCUIT CURRENT: A_{DC}
	"WARNING: PV ARRAY D.C. ISOLATORS DO NOT DE-ENERGIZE THE PV ARRAY AND ARRAY CABLING" Black lettering on a yellow background.	**WARNING** PV ARRAY D.C. ISOLATORS **DO NOT** DE-ENERGIZE THE PV ARRAY AND ARRAY CABLINGS

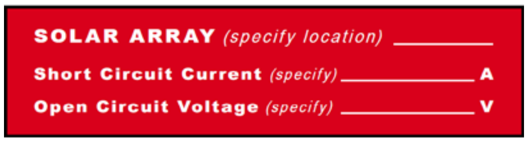
	Install where multiple DC isolators are connected to inverter: "WARNING: MULTIPLE D.C. SOURCES TURN OFF ALL D.C. ISOLATORS TO ISOLATE EQUIPMENT" Black lettering on a yellow background.	
7. AC isolator enclosure adjacent to array	Labelling that matches shutdown procedure 'Inverter A.C. Isolator' or similar	
8. PV system monitoring and communication device/s[1]	Install sign "Do not switch off power supply" on power outlet for PV system monitoring device/s.	
9. Access to Inverter station	Where system maximum voltage exceeds 600V DC, install sign: WARNING HAZARDOUS VOLTAGE AUTHORIZED ACCESS ONLY Black lettering on a yellow background.	

[1] PV system monitoring devices may be placed in distribution boards. Same signage rules will still apply

LABELLING AT DISTRIBUTION BOARDS AND SWITCHBOARDS



Location	Labelling Requirement	Label example
10. AC circuit breaker at the Point of Connection (POC)	"INVERTER SUPPLY MAIN SWITCH" or similar	MAIN SWITCH INVERTER SUPPLY
11. Within distribution board to which inverter is connected	Shutdown procedure: Ensure that the descriptions in the procedure match the labels on the isolators to which they are referring.	SHUTDOWN PROCEDURE 1. Turn off the switch labelled 'inverter AC Isolator' located next to the AC terminals of the inverter 2. Turn off the switch labelled 'PV Array DC Isolator' located next to the DC terminals of the inverter **WARNING**: DO NOT OPEN PLUG AND SOCKET CONNECTORS OR PV STRING ISOLATORS UNDER LOAD PV ARRAY OPEN CIRCUIT VOLTAGE: V_{DC} PV ARRAY SHORT CIRCUIT CURRENT: A_{DC}
	"WARNING: PV ARRAY D.C. ISOLATORS DO NOT DE-ENERGIZE THE PV ARRAY AND ARRAY CABLING" Black lettering on a yellow background.	

	"Warning dual supply isolate normal and inverter supply before working on this switchboard" sign provided in the distribution board.	
12.1 Main switchboard	Label grid supply "MAIN SWITCH NORMAL SUPPLY" or similar	
	Fire emergency information sign as per AS5033 requirements	
	Sign displaying location of distribution board to which inverter supply is connected as per AS 4777.1 requirements. (Required on boards not directly connected to the inverter)	
	Sign indicating Inverter location	
	Circular green reflector sign at least 70 mm in diameter displaying the letters 'PV' installed on exterior of switchboard and visible on approach. Also required at Meter box.	

12.2 Other distribution boards	Sign displaying location of distribution board to which inverter supply is connected as per AS 4777.1 requirements (Required on boards not directly connected to the inverter)	**WARNING** DUAL SUPPLY ISOLATE SOLAR SUPPLY AT DISTRIBUTION BOARD ________________ BEFORE WORKING ON THIS SWITCHBOARD

15.10 ATTACHMENT 10: PV SYSTEM COMMISSIONING

The PV system installer must commission the grid-connected PV system once installation has been completed. The documented results of the system commissioning will confirm that the system meets the system design and is structurally and electrically compliant with the relevant standards and guidelines.

The commissioning requirements as per Australian standards AS/NZS 5033 must be met as a minimum.

As part of system commissioning, the installer will verify that the system is installed correctly using an installation checklist to document this process. The installer will then test the system and record the results in a test record document. The installation checklist and test records together form the system commissioning sheets. Australian standards AS/NZS 5033 requires the PV system's completed commissioning sheets are to be included in the system documentation given to the PV system owner.

The following pages contain an example of an installation checklist and test record suitable for use as part of the system commissioning.

At the time of writing (2015) The Clean Energy Council offers a recommended installation checklist and a Commissioning App, which can be accessed by accredited installers for PV system commissioning.
Installers are to comply with all OHS standards and guidelines when performing system commissioning and must ensure that all test procedures will not negatively impact the systems operation.

INSTALLATION CHECKLIST

Installer name:	
Installer accreditation number:	
Installer signature:	
Commissioning date:	
Installation address:	
PV module manufacture:	PV module model number:
PV modules comply with relevant building codes: YES ☐ NO ☐	
All PV modules connected to the same MPPT are of the same make and model or have similar rated electrical characteristics: YES ☐ NO ☐	
All PV modules connected to the same string have the same angle of altitude and azimuth: YES ☐ NO ☐	
Number of modules in series: String 1: String 2: String 3: String N:	Number of strings in parallel: Sub-Array 1: Sub-Array 2: Sub-Array 3: Sub-Array N:
Array mounting system manufacturer:	
Array mounting system type:	
Array mounting system certified for installation site parameters: YES ☐ NO ☐	
Array mounting system does not use or contact any galvanically dissimilar metals: YES ☐ NO ☐	
All penetrations and fixings are suitably sealed and weatherproofed: YES ☐ NO ☐	
PV array voltage complies with site regulations: YES ☐ NO ☐	
PV system wiring is suitably protected from mechanical action: YES ☐ NO ☐	
PV array uses single core double insulated cabling compliant to relevant standards: YES ☐ NO ☐	
Overcurrent protection is provided where required: YES ☐ NO ☐ NOT REQUIRED ☐	
All components used are rated for DC usage and have voltage ratings greater than or equal to the PV array maximum voltage: YES ☐ NO ☐	
All components are rated suitable to their environment and have the appropriate IP and UV ratings: YES ☐ NO ☐	
Disconnection devices and protection devices (where installed) are readily available in the case of maintenance or emergency: YES ☐ NO ☐	
Disconnecting devices comply with frequency of usage requirements and are rated for the temperature adjusted operational circuit current: YES ☐ NO ☐	
Switch-disconnectors are rated to switch full load currents, are not polarity sensitive and grade with overcurrent protection (where required): YES ☐ NO ☐	

PV array switch-disconnectors interrupt all live conductors: YES ☐ NO ☐
PV conductor current carrying capacity is equal to or greater than: (i) the potential system fault current or (ii) the overcurrent protection (where installed): YES ☐ NO ☐
PV cabling, where exposed to the elements, is UV-resistant or installed in UV-resistant enclosures: YES ☐ NO ☐
A method of securing cabling has been used which will last the lifetime of the system: YES ☐ NO ☐
DC cabling within buildings is enclosed in heavy-duty rated protection: YES ☐ NO ☐ NOT REQUIRED ☐
Combiner boxes are installed according to manufacturer recommendations: YES ☐ NO ☐
Combiner boxes are suitably protected from the environment using appropriate bottom entry cable glands: YES ☐ NO ☐
Double insulation between all conductors is maintained throughout the system: YES ☐ NO ☐
PV plugs, sockets and connectors comply with relevant standards, are rated for the installation environment and only connect with the same make and model: YES ☐ NO ☐
Blocking and bypass diodes, where installed external to the PV module are suitably protected and grade according to relevant standards and system parameters: YES ☐ NO ☐
Overcurrent protection (where required) is installed at the end of the conductor which is most electrically remote from the PV modules: YES ☐ NO ☐ NOT REQUIRED ☐
Switch-disconnector is mechanically interlocked with or located adjacent to the inverter if the array is not in line of site or if it is greater than 3 metres away: YES ☐ NO ☐
Where multiple disconnection devices are installed they are ganged together or grouped and labelled such that it is clear all must be operated to isolate the system: YES ☐ NO ☐
All exposed metal module frames and mounting equipment are earthed and equipotentially bonded in accordance with the relevant standards: YES ☐ NO ☐
Equipment used for PV module and mounting frame earth connections is fit for purpose: YES ☐ NO ☐
Earthing has been arranged so that the removal of a single module earth connection will not disrupt the continuity of the bonding connections for the rest of the array: YES ☐ NO ☐
Earthing conductor type and size comply with the relevant standard: YES ☐ NO ☐
PV array functional earthing is done close to or within the inverter and is done according to the relevant standards: YES ☐ NO ☐ NOT REQUIRED ☐
The inverter complies with the relevant country standards: YES ☐ NO ☐
The inverter installation complies with manufacturer’s instructions, DNSP rules and regulations and relevant state legislation:

YES ☐ NO ☐
Inverters connected to LV PV arrays have an internal or external earth fault alarm system: YES ☐ NO ☐
Inverters connected to arrays with direct functional earthing have an earth fault interrupter which will shut the PV system down and provide a fault alarm when an earth fault occurs: YES ☐ NO ☐ NOT REQUIRED ☐
Signage and labelling conforms to the relevant standards and guidelines: YES ☐ NO ☐

EXAMPLE TEST RECORDS

PV Array DC:

If array is LV (>120 V) there is no voltage on input side of array combiner box (if one is installed)	☐
There is no voltage on output side of array combiner box (if one is installed)	☐
Continuity between strings and array combiner 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	☐
Correct polarity between strings and array junction box:	
String 1	☐
String 2	☐
String 3	☐
String 4	☐
Open circuit voltages:	
String 1	V
String 2	V
String 3	V
String 4	V
Continuity between array combiner box and PV array DC isolator:	
Sub-Array +ve	☐
Sub-Array -ve	☐
Correct Polarity between Array Junction Box and PV array DC isolator	☐
Sub-Array Voc	V
Short Circuit Currents:	
String 1	....A
String 2	....A
String 3	....A
String 4	....A
Short Circuit Current Array	....A
Reconnect the strings one at a time by reconnecting the string overcurrent protection (either fuses or circuit breakers) and connecting any disconnectors.	
Open Circuit Voltage at input side of PV array DC isolator	V

Continuity between PV array DC isolator and Inverter:	
Array +ve	☐
Array -ve	☐
Correct Polarity between PV array DC isolator and Inverter	☐

Inverter AC:

Continuity between Inverter and kWh meter:	
Line	☐
Neutral	☐
Correct polarity between inverter and kWh meter	☐
Continuity between kWh meter and PV inverter AC isolator:	
Line	☐
Neutral	☐
Correct Polarity between kWh meter and PV inverter AC isolator	☐
Correct Polarity at output of PV inverter AC isolator from grid	☐
Voltage at output of PV inverter AC isolator from grid	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 array DC isolator followed by inverter AC isolator, but the procedures as recommended by the inverter manufacturer must be followed.*	
System connects to grid	☐
When inverter AC isolator and PV array DC isolator turned on and inverter start-up procedure followed	
Voltage at DC input of inverter	V
Voltage within operating limits of inverter	☐
Voltage at AC output of inverter	V
Input power of the inverter (If available)	....W
Output power of the inverter (If available)	....W
Output power as expected	☐
System disconnects from grid when inverter AC isolator turned off	☐

ATTACHMENT 11: PV SYSTEM MAINTENANCE

Prior to performing any maintenance, follow shut down procedures as specified on the system signage installed or in system documentation provided by the system provider. If these shutdown procedures are not available, follow the following procedure:

1. Turn off the Solar Supply Main Switch in the AC switchboard to which the PV system is directly connected;
2. Turn off the Inverter AC isolator at the inverter (if provided);
3. Confirm that the inverter has been disconnected from the grid and has stopped operation. This is usually displayed as a grid fault;
4. Turn off the PV array DC isolator at the inverter;
5. Turn off the PV array DC isolator at the array.

All maintenance on the PV system should be conducted in accordance with documentation provided by the system provider. In the event that one does not exist the following has been produced and must be implemented as a minimum.

Activity	Frequency
Visually inspect PV modules • Defects, such as yellowing, micro cracks and hotspots; • Dust/dirt build-up.	Annually
Check mechanical integrity of the array structure • Screw and boards are secure; • No signed of cracks, corrosion of other weakness.	Annually
Clean modules • Using water only; • Avoid directly spraying water onto cabling, junction boxes and PV array isolator enclosures.	As required (dependent on site)
Trim vegetation shading the array	As required (dependent on site)
Inspect and clean inverter • Clearance for ventilation is maintained • Any ventilation vents are clear • Inverter is securely mounted to the wall	Annually
Check all cabling and conduit: • Mechanical damage • UV damage	Annually
Check output voltage and current of each string of the array and compare to the expected output under the existing conditions.	Annually
Check electrical wiring for loose connections	Annually
Check the operation of the isolators and circuit breakers. • Rooftop and inverter PV Array DC Isolators; • Inverter AC Isolation; • Solar supply main switch.	Annually
Check monitoring system: • Logging production data; • Functioning network connection for remote monitoring and earth fault notification (if applicable).	Annually
AC Cabling and isolation must be inspected in accordance with CIS electrical switching and infrastructure maintenance procedures.	Annually