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E.3.5 PHOTOVOLTAIC SYSTEMS

E.3.5.1 GRID-CONNECTED PHOTOVOLTAIC SYSTEMS

A grid-connected photovoltaic (PV) system, normally includes the following components and items:
- PV Panels
- PV framing and fixing
- Grid-connected inverters
- DC boards, cabling and protection
- AC boards, cabling and protection
- Earthing, surge and lightning protection
- Protection as required by the corresponding distribution network service provider
- Grid connection point
- A network connection agreement
- Metering and monitoring system (including weather station)
- Signage and labelling

All grid-connected PV systems installed on UNSW grounds and buildings must synchronize with the grid and generate power at 415/240 Volts, 3 phase, 50 Hz. All solar modules, cables, inverters and controls must be suitable for connection to the low voltage distribution system of the selected location.

The equipment must be of standard proprietary design, provided by a manufacturer experienced in the detailed design, installation and commissioning of commercial solar PV systems.

All final testing, commissioning, and relevant electricity distribution network service provider (DNSP)- i.e., Ausgrid- witnessing including measurement of system performance must be carried out by the manufacturer/installer in conjunction with UNSW.

E.3.5.2 STANDARDS AND ACCREDITATIONS

The installation of all PV systems on UNSW shall meet all relevant legislation including current Australian standards, DNSP network connection requirements and all the applicable requirements of the Building Code of Australia (BCA).

Key relevant standards include, but are not limited to;
- NSW Service and Installation Rules
- NSW Department of Water and Energy
- The Supply Authority Rules and Regulations
- Australian Communications Authority
- Australian standards including the latest or equivalent versions of:
  - AS/NZS 1170 – Structural Design Actions
  - AS/NZS 1664 – Aluminium Structures
  - AS/NZS 2053 – Conduits and Fittings for Electrical Installations
  - AS 2676 – Installation, Maintenance, Testing and Replacement of Secondary Batteries in Buildings
  - AS/NZS 3000 – Wiring Rules
  - AS/NZS 3008 – Electrical Installations – Selection of Cables
  - AS/NZS 3013 – Electrical Installations – Wiring Systems for Specific Applications
  - AS/NZS 61439– Low Voltage Switchgear and Control Assemblies
  - AS 4070 – Recommended Practices for Protection of LV Electrical Installations
  - AS/NZS 4777 – Grid Connections of Energy Systems via Inverters
  - AS/NZS 5033 – Installation of Photovoltaic (PV) Arrays
  - AS/NZS 5139 – Safety of battery systems for use with power conversion equipment.
  - AS/NZS 1768 – Lightning Protection
- Ausgrid NS194 Protection Requirements of Embedded Generators >30kW
- Ausgrid NS194a Guidelines for Photovoltaic installations up to 200kW connected via invertors to the Ausgrid network

All PV systems must comply with all the requirements from the Clean Energy Regulator and be eligible for the creation of Large-scale Generation Certificates (LGCs). The Contractor responsible for the design and installation must be accredited by the Clean Energy Council (CEC), in order to undertake solar PV design and installation works.

E.3.5.3 GENERAL DESIGN PRINCIPLES

The location and design of PV arrays must maximise solar power generation within the specified available space; hence, shading from surrounding obstacles should be avoided as much as possible. Specifically, the system design must ensure that PV modules will not be shaded to any extent by existing surrounding buildings, vegetation or other structures for at least 6 hours a day during all summer and winter months (e.g., 10 AM to 4 PM for north facing modules). PV modules shall have a minimum of 5 degrees inclination for self-cleaning.

The arrangement of the system must be such that the modules are grouped together symmetrically in an aesthetic manner and that easy access to all PV panels is provided, to allow for cleaning and maintenance, by means of clear access corridors. As a maximum, the removal of one panel to access another panel will be accepted.

In the case of a rooftop system, the panel layout must allow for continuous access to the perimeter roof gutter system and ensure that the PV system does not adversely affect the design of any existing roof purlins, rafters and their fixings. Additionally, if the proposed layout interferes in any way with the existing fall prevention/arrest system, then a new fall prevention/arrest system must be provided, to be compliant with all relevant Australian codes and regulations. An engineering certification of the design and its impact on the structure must be provided.

UNSW requires the inverters to be located indoors (e.g., inside a plantroom); otherwise, if necessary, the inverters maybe installed outdoors if they are protected from direct sun and rain and follow all manufacture's requirements for outdoor installation. The inverters must be easily accessible for maintenance or in an emergency. Ideally, the inverters shall be close to the PV arrays in order to minimize DC cable length and losses.

E.3.5.4 PV MODULES

The nominated solar PV module shall be mono or multi crystalline silicon cells with a minimum module efficiency of 19.0% under standard test conditions (STC) and be selected such that they maximise the energy production over their life cycle for the site conditions provided. Furthermore, the proposed PV module must comply fully with the following technical details:

- The PV modules must meet the requirements of AS/NZS-5033 and be currently in the 'building approved modules' list from the CEC.
- The PV modules must be labelled with the correct Certifier Mark.
- The PV modules must be certified to IEC-61215.
- The PV modules must be certified to IEC-61730 (including fire test MST-23).
- The PV modules must meet Application Class A of IEC-61730.
- The PV modules must be certified Fire Safety Class C or better.
- The PV modules must be Class I as defined by AS/NZS 3000.
- The PV modules must be encapsulated in toughened glass.
- The PV junction boxes must be UV resistant and IP65 compliant or better, as per AS 60529.
- The PV module's power temperature coefficient must be ≤ 0.40%/°C
- The PV module's operating temperature shall be -40°C to +85°C
- The PV module's mechanical protection is to withstand hailstone impact damage
- The maximum allowable mechanical wind and snow load to be at least 2400 and 5400 Pa, respectively
- The PV modules must be installed in full accordance with the manufacturer's installation, operation and maintenance instructions.

- The PV modules must have at least 10-year product warranty and 25-year power output warranty that guarantees output capacity of at least 95% for 5 years, 90% for 10 years, 87% for 15 years, 83% for 20 years and 80% for 25 years.

E.3.5.5 MOUNTING SYSTEM

The mounting system must be soundly fixed to the primary structure (being either a roof or a purposely build supporting structure). A registered professional structural engineer must certify the finished installation.

If pertinent, UNSW may also accept clip-on clamp systems that avoid the need of roof penetrations, given that, they are approved by the structural engineer and comply with the relevant standards and warranty requirements. The mounting system along with all its components must have a minimum product warranty of 10 years.

The PV array mounting frame and fixtures must be suitable for the regional maximum wind speeds and corrosion due to the close marine environment. The design life of the structure is to be at least 30 years. The mounting structure and fixings shall comply fully with the requirements of AS/NZS 1170.2: Structural Design Actions – Wind Actions, as well as with AS/NZS 5033: Installation and Safety Requirements for Photovoltaic (PV) Arrays (particularly, but not limited to, section 2.2.5).

Rubber gaskets shall be used to separate dissimilar metals to prevent galvanic reaction and any bolts, washers, screws, nails or metal objects in contact with the mounting frame must be rust-proof. In the case of rooftop systems, the watertight nature of the existing roof is to be maintained at all times.

E.3.5.6 INVERTERS

The grid-connected inverter must fully comply with relevant Australian and International standards, including but not limited to the most up to date versions of AS/NZS 4777, AS/NZS 5033, IEC 62109-1 and IEC 62109-2. All inverters must be on the CEC list of approved inverter and power conversion equipment. Standard string inverters as manufactured by SMA (or other as approved by UNSW) are preferred; however, micro-inverters and DC/DC optimizers can be proposed as options.

Inverters shall have IP65 or higher protection. Protective shrouds shall be provided for all cable terminations. The isolation of control and instrumentation wiring shall be by insulated covers and separation. Note that Clause 7.5.4 of AS/NZS 61439 must be complied with.

The inverter(s) shall be capable of autonomously synchronizing with the electrical system and be able to operate within the parameters established by the network operator. Each inverter shall have a true sine wave with harmonic distortion <4% of output current, a European efficiency rating of at least 97%, and protection for overload, short circuit and transient conditions. The output electricity supply from each inverter may be single (1) or three (3) phase system configured for connection to a local 415/240V, 3 phase AC switchboard(s), which shall then be connected, by one (1) three phase feeder, to the building electrical system. The inverter AC power system to each building shall be balanced over the 3 phases within 5% of optimum operating conditions.

DC isolators for all strings are to be installed adjacent to the inverters (in the DC switchboard) as per AS/NZS 5033 standard. This is in addition to any built-in DC isolator that the inverter might have. This is to minimise electric shock hazards when inverters must be replaced, as per clause 4.4.1.2 in AS/NZS 5033.

The solar equipment including the proposed inverters shall be well ventilated to prevent over-heating and shall be capable of withstanding the extreme outdoor temperatures that can be reached during the day on Sydney’s summer period. Over-temperature protection shall be provided to protect the complete

PV system on periods when the equipment is operating outside its safe operating temperature range. The protection is to shutdown the entire PV system including inverters.

All inverters shall have a minimum product warranty period of at least 10 years and include a front LCD panel display with relevant information of the performance and health of the inverter.

E.3.5.7 WIRING

Wiring for the DC and AC systems shall be colour coded to relevant and current standards and to the approval of UNSW. High temperature insulated copper conductors shall be used, e.g., XLPE or equivalent.

Non-proprietary field connections shall be connected to DIN rail mounted terminal strips having 25% spare terminal capacity. The terminal strips shall be insulated, double screw, recessed clamp type and minimum size 6 mm^2 to approval. Terminal strips shall be appropriately housed and clearly labelled. Wiring shall be labelled or numbered by means of permanently fixed interlocking ferrules attached at each termination.

Label each module and all controls and equipment with engraved laminated type labels, screw fixed to modules and all other associated equipment forming part of the PV system installation.

The system shall incorporate cable trays and or ducts to support all DC and AC cables including all supports and fixings, as well as cable trays/ducts and supports for the RS 485 cables linking the monitoring system to the inverters and metering cabling.

All DC cabling layout is required to follow industry best practice avoiding dangling wires from the back of the modules and with all exposed wiring on the roof to be laid out in UV rated conduits. The array must be wired in a way that minimises conductive loops as per AS/NZS 5033. All MC4 connectors should be also covered by the modules to avoid direct exposure to rainfall.

E.3.5.8 SYSTEM CONNECTION, ANCILLARY WORKS & CENTRALISED PROTECTION

New DC and AC solar distribution boards are to be installed near the inverters. The AC solar distribution board must provide a main LV 415/240V 3-pole suitably rated circuit breaker to provide protection to the cable from the distribution board to the building AC bus-system. Note that connectors must be compliant with EN 50521:2008 + Appendix 1:2012, and PV array cables must conform to PV1-F, in line with the Clean Energy Council guidelines.

The respective AC switchboards and LV cable connections to the university's LV system must be over-sized by a minimum 20% of the maximum output rating of the inverters.

If roof array DC isolators are used, they must have one entry point on the bottom of the isolators to minimize water ingress. The entry point should have 4-hole multi hole grommet inside a compression gland that allows a complete seal around cables. The DC isolators are also required to be covered by a metal shed to avoid direct rainfall exposure. The PV designer can propose alternative solutions to roof array DC isolators as per AS/NZS 5033.

It is a requirement of AS/NZS 4777 that, where multiple IES are connected to a single distribution grid supply point, a centralized protection system must be installed. The current solution, adopted by UNSW, is for the main PV system AC circuit breaker (CB) to be tripped remotely through an external signal. The external trip signal is provided from a detection device at each connection point of the university's private HV network to the DNSP distribution grid (also known as HV Intake substations). When a disconnection event is detected (either grid faults or reverse power), then a trip signal is sent over a wireless network, via line-of-sight transmitter/receiver pairs, to all PV systems located in the HV network

linked to that grid connection point. All new PV installations must connect to the existing wireless infrastructure to comply with AS/NZS 4777 or provide a compatible solution in the case the corresponding grid connection point (e.g. HV substation) does not have a centralised protection system.

E.3.5.9 LIGHTNING PROTECTION & SURGE PROTECTION

If required, an appropriate lightning protection system must be designed and engineered for the protection of the PV system and structure, including a transient voltage and lightning surge diverter to exposed elements (like cabling), as per AS/NZS 1768, AS/NZS 5033 and AS/NZS 3000. Primary point of entry surge diversion at the new switchboards is required to limit the level of incoming voltage surges. If the building has an existing lightning protection system, AS/NZS 5033 requirements for DC surge protection devices must be followed (Table F1 in AS/NZS 5033). Surge Protection Devices (SPD) installed on the PV array must be explicitly designed and manufactured for DC PV application.

All exposed conductive parts of the PV system, including PV module frame and mounting rails must be earthed in accordance with AS/NZS 3000 and the Supply Authority Regulations for a Multiple Earthed Neutral system. Additionally, the DC earthing shall comply with CEC requirements.

E.3.5.10 METERING AND MONITORING

A monitoring system must be included with each PV system with a compatible weather station that measures ambient temperature, module temperature and solar irradiance. The monitoring system must be capable of recording inverter level data and weather data at 5 min intervals and provide alarms in case of loss of performance or hardware failure. The monitoring system must be able to export data to an online system and be accessible via FTP to UNSW so data files can be downloaded when required. The preferred monitoring solution is based on the SMA Data Manager M in conjunction with SMA COM Gateway (if needed) and SMA Sunny Portal. An alternative solution can be proposed and will be analysed by UNSW on a case-by-case basis.

An electricity meter must also be provided and installed per connection point (switchboard) of the PV system to UNSW's electrical network, complete with CTs, terminals, etc., to measure and log the AC power generated by the inverters connected to the LV network. The meter shall be configured to record import (self-consumption) and export (generation) power from the PV system and installed in the AC distribution boards. The electricity meter and installation are to comply with the UNSW Metering guidelines and to be connected to UNSW monitoring system EMACS. Minimum size conductors for CT connections shall be as specified in the UNSW Metering Guidelines.

E.3.5.11 DISTRIBUTION BOARDS

E.3.5.11.1 MINIATURE CIRCUIT BREAKERS

Circuit breakers shall be of a manufacture to match existing and have instantaneous short circuit and inverse-time over-current tripping characteristics and shall have positive identification for "ON", "OFF" and "TRIP" positions. Circuit breakers shall have symmetrical RMS fault interrupting capacities to suit potential let through fault currents on the system and as indicated on the drawings.

E.3.5.11.2 RESIDUAL CURRENT CIRCUIT BREAKERS

Residual current protection shall be provided to all lighting and power final sub circuits in accordance with AS/NZS 2000:2007.

Where required, residual current protection shall be provided via Merlin Gerin RCD (or other approved by UNSW) protected circuit breakers located at the associated switchboard. The RCD circuit breakers shall have a 30mA rating (Type 2 – AS3190) as specified in AS3000-2007. Any outlet not RCD protected shall be provided with a label "OUTLET NOT PROTECTED BY RCD".

E.3.5.11.3 CONTACTORS

Contactors, where provided, shall be in accordance with relevant Codes and Standards and shall be capable of one million (1,000,000), no-load operating cycles and be rated to AC3. All contactors shall incorporate a minimum of two (2) normally open and two (2) normally closed auxiliary contacts.

E.3.5.11.4 CONTROL SWITCHES

Switches shall be type tested for a minimum of one million (1,000,000) operations under the design conditions applicable to these works. Selector switches shall be cam operated rotary type.

E.3.5.12 LABELLING

All switchgear, apparatus and controls shall be labelled in accordance with the local Supply Authority's requirements, this Specification and the relevant Codes and Standards. Labels shall be manufactured from multi-layer PVC material to produce black letters on a white background. The letters and numerals shall be machine engraved to the sizes noted below.

Labels shall be fixed to the parent surface using either screws or escutcheon pins to approval. The use of an adhesive alone is not permitted. All removable panels shall be labelled to warn of the possible exposure to live equipment and busbars. Terminal strips shall be labelled to identify the circuit number, phase connection, terminal number and function. All labels and lettering shall be horizontal.

Labels shall follow the following format:
Distribution Board Designation: 10.0 mm. Letters i.e. switchboard
Main Components: 5.0 mm. Letters (Rating – 400 A)
Minor Components: 5.0 mm. Letters (Supply cable size and type)

Nameplates shall be provided in accordance with AS/NZS 61439. Label schedules shall be submitted to UNSW for review prior to manufacture.

E.3.5.13 CABLING

Wiring shall be sized to comply with the AS/NZS Wiring Rules for the actual circuit loading or as specified. Cables shall be brought to the site in their original packages with their labels intact otherwise they shall be liable for rejection. All wiring in which kinks or abrasions occur shall be condemned and shall be replaced without cost to the principal.

All cables shall be handled, drawn in and fastened with care to ensure that damage is not caused to the cable. The manufacturers recommended minimum bending radius for each type of cable shall be determined and strictly adhered to.

Any cable damaged during installation shall be withdrawn and replaced entirely. No damaged section of cable shall be left in circuit.

No joints or splices of any type shall be permitted in the cable between the designated beginning and end points for each circuit.

No cables shall be left in such a situation as to apply pressure or tension to the cable at any point where it leaves the ceiling space, conduit, cable tray or the like.

E.3.5.13.1 CABLE TRAYS

DC cables on roof are to be mounted on galvanized steel trays. Cable trays shall be adequately stiffened and braced, both transversely and longitudinally, to ensure a true finished run of cable and tray.

All bends, tee-offs, changes in section and changes in direction shall be made with factory manufactured fittings. Jointing shall be butt joints made with approved jointing plates. Lapped joints will not be permitted.

E.3.5.13.2 WIRING DUCTS

All wiring ducts shall be fixed on a continuous galvanised M.S. angle iron or "Unistrut" support system, which shall be suspended or bracketed at intervals sufficiently small to produce a robust, rigid installation and to ensure no appreciable deflection between supports.

All screws, nuts, washers, etc., used throughout the installation shall be galvanised steel. Screws shall be cut off flush with the top of the unit after erection and shall be filed smooth and painted with approved aluminium paint.

E.3.5.13.3 CONDUIT

TPS cables must be protected by conduit where it is exposed to damage or where embedded in plaster or the like. Conduits may be either steel or PVC, be of minimum 25mm diameter, subject to the following requirements.

- UV rated conduits to be used where exposed to sunlight.
- Where conduit is cast in concrete or installed in wall chases, in any location, then heavy duty PVC conduit is acceptable.
- All rigid conduits shall conform to the "Industry Standard Rigid Steel Conduit Association", and shall further conform to all requirements of the National Electrical Code as determined by Underwriters' Laboratories, Inc.
- All cables installed in ceiling spaces shall be supported from the existing building structure by an approved method.
- Cable passing through metal wall frames, etc.; shall be protected from damage using an approved cable glands or grommets.

All conduit penetrations of roofing and other waterproofing membranes or surfaces must be approved by the Consulting Engineer and Proprietor. Provide all necessary sleeves and flashings to the satisfaction of the Consulting Engineer and UNSW. All components and ducting exposed to the outdoor environment must be a minimum of IP55 compliant and must be UV resistant.

E.3.5.14 TESTING AND COMMISSIONING

The solar PV system installations and equipment shall be fully tested on site by the Contractor prior to connecting system to the building power distribution system. The test shall include but not be limited to:

- Power, frequency and voltage withstand test on the main circuit in compliance with AS/NZS 61439.
- Insulation resistance.
- Continuity of all wiring and control circuits.
- Operation of inverter, switches and indicators, etc.
- Functional operation and interlock checks of all control circuits including simulated operation.
- The relevant electricity distribution network service provider (DNSP) testings and approvals (e.g., Ausgrid witness testing and Ausgrid approval to connect the system to the grid).

After installation, testing and commissioning is complete, and the solar PV installation is placed into service, site measurements shall include but not limited to:

- Verify that the PV array is being switched in and out correctly to maintain power flow and voltage levels between pre-set limits agreed with UNSW.
- Determine the level of harmonic voltages present on all phases using a harmonic voltage analyser with print-out.
- Determine the range of system load current and power.

- Determine the range of system phase voltages.
- Climatic data including solar irradiation.

Throughout a typical day, measurements shall be taken and recorded at different times of the day to establish the PV system output capacities for each array.

E.3.5.15 DEFECT LIABILITY PERIOD AND MAINTENANCE

A twelve months defects liability on the entire installation is to be provided. During the Guarantee and Maintenance period, the Contractor shall be entirely responsible for:

- Carrying out regular inspections and full servicing of all equipment installed under this specification; providing a “call out” service for breakdowns, at any time during normal operating hours.
- If during the guarantee and maintenance period any item of equipment should fail, then the Contractor shall promptly replace all such equipment at no cost and with minimum inconvenience to UNSW. The Contractor shall work overtime to meet this requirement where appropriate.
- Where overseas equipment is involved, the Installer shall air freight out any parts needed.
- The cost of providing the above services shall be included in the tender sum.
- The Contractor’s order for the specified equipment shall include the warranty service for it, for the duration of the specified guarantee and maintenance period. This is to ensure that the manufacturer is responsible for the servicing of their equipment.

The Contractor shall perform, as a minimum, the maintenance work specified herein, and any additional work needed to keep the equipment in sound condition and operating in a satisfactory way, including work recommended by the manufacturers of equipment and accessories, leaving all of the equipment installed under this specification in perfect operating condition at the end of the defects’ liability period.

The contractor shall provide UNSW with copies of all of the systems’ manufacturer’s warranties and guarantees and ensure that all remedies and rights under the guarantees and warranties are transferred to UNSW at the end of the Defect Liability period.

The Contractor shall provide the guaranteed energy yield for the defects’ liability period. As an option, the Contractor can also submit a three-year guarantee with an annual maintenance plan with the associated guaranteed energy yields for the period.

Maintenance to manufacturer’s requirements for the first year is part of the Scope of Work. This includes minimum of two (2) six monthly on-site cleaning of solar panels and other necessary maintenance, as per manufacturers requirements. During this maintenance period, a check on the electrical connections at inverters and switchboards shall be carried out. A Maintenance report shall be provided to UNSW for their information and records after each six-monthly visit. The scope of maintenance work shall be included in the tender documents.

Under the maintenance agreement, when an issue is reported, UNSW requires a response within 48 hours.