Standard Specification

E-SPE-STD-024 Solar PV

Document number: SPE-00517

Ver no.	Description	Owner		Approved for issue		
		Position	**Approval**	**Position**	**Approval**	**Date**
1	Original Version	Team Leader OT Architecture & Energy	Refer to supporting Info in REX	Manager DTI Performance	Refer to supporting Info in REX	08/12/2022
This Engineering Standard was endorsed by RPEQs on behalf of Seqwater.						

Version History

Ver	Date	Description	Author	SME	Owner	Approver
0.1	17/05/2022	Draft Issue				
0.2	22/07/2022	Update for comments				
0.3	09/09/2022	Final Issue				
0.4	10/11/2022	Updated for RPEQ details				
1.0	11/11/2022	Initial Issue				

(Refer Controlled Document in REX for Author, SME, Owner and Approver details)

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1 Purpose

This document is part of a suite of Seqwater Engineering Standards which are in alignment with the Seqwater Quality Management System. Their purpose is to provide a consistent approach to the development, modification, and management of Seqwater infrastructure that is fit for purpose and safe.

This Standard Specification provides the minimum requirements and recommendations for Solar Photovoltaic (PV) Design and Construction. This document must be used in conjunction with the documents it references to assist in ensuring a fit for purpose Solar PV plant.

This Standard Specification is not intended to be relied upon solely for design, supply and installation works; advice from specialist engineers and/or Manufacturers may be required on a case-by-case basis.

This Standard Specification shall only be applied for grid connected Solar PV Plants with aggregate maximum system capacity of less than 5 MW_{AC} and above 1 kW_{AC}.

2 Application of Standard Specification

This Standard Specification applies to all Seqwater employees, suppliers, contractors and consultants working for, or on behalf of, Seqwater unless otherwise stated. It applies to all new assets and to all existing assets undergoing refurbishment or modification. It must be used in conjunction with other relevant Seqwater Engineering Standards and project specific documents to define the technical requirements for infrastructure design and construction.

Seqwater Engineering Standards detail Seqwater's minimum requirements and recommendations to provide infrastructure that will be fit for purpose, and safe to operate and maintain. However, at all times the designer remains responsible for ensuring infrastructure designed is fit for purpose and safe to construct, operate, maintain, and demolish. In doing so the designer must exercise appropriate due diligence to identify and manage hazards so far as is reasonably practicable.

Designers must also ensure compliance with relevant Australian Legislation, Standards, Codes and Guidelines (including those produced by WSAA). Where no Australian Standard exists for a particular application, work must conform to the most current version of an industry accepted international standard.

Deviation from meeting the minimum requirements in this standard requires written agreement from Seqwater as per the deviation process detailed in Procedure X-*PRO-STD-008 Asset Standards Management and Application*. This process includes completion of an Asset Standards Deviation Request Form and submission via the Seqwater Project Representative (for external parties) or via Seqwater's Engineering Mailbox (engineering@seqwater.com.au) (for internal parties).

Where noted in this Standard Specification that Seqwater approval or acceptance shall/must be sought, approval or acceptance must be gained through the Seqwater Asset Standard Deviation process, as identified above.

Responsibility for ensuring compliance with Seqwater Engineering Standards lies with those engaged in the management and execution of design, construction, and modification of Seqwater assets. This includes modifications to the functional design of the asset including technical changes made which would extend an asset outside of its design operating envelope and/or approved operation and maintenance practices.

In the case that it is identified that a specific requirement within this Engineering Standard does not meet the requirements of project specific documents, another Seqwater Engineering Standard or Australian Legislation, Standards, Codes or Guidelines, the conflict must be brought to the attention of the Seqwater Principal Engineering Standards and Assurance (or their delegate) via the Engineering Mailbox, and written agreement must be gained prior to application of the requirement.

Advice must be sought from Seqwater to clarify any ambiguities regarding this Engineering Standard.

Seqwater undertakes regular updates of its Engineering Standards. Before utilising this Engineering Standard, the complete list of Seqwater Engineering Standards should be reviewed, to ensure currency and applicability of standards to be applied to the works.

This document must be used in conjunction with the documents it references in order to assist in ensuring a fit for purpose asset.

3 Definitions

The following definitions (Table 3-1) apply to this Standard Specification.

Table 3-1 – Definitions

Term	Definitions
Connection agreement	An agreement between the Principal/Seqwater and the Network Service Provider that sets out the necessary terms and conditions upon which the Principal/Seqwater is connected to the Distribution System.
Contract	Legally binding document in which Seqwater and the Contractor who undertakes the Works has agreed upon to provide the defined scope of work.
Contractor	An entity engaged by Seqwater to undertake work in accordance with an agreed contract and defined scope of work.
Defects Liability Period[1]	Fixed period of time, commencing from the start of the practical completion, during which the Contractor has agreed contractually to return to the site to rectify defects
Facility	The site in which the Solar PV System is established
Final Completion[1]	The last stage is final completion, which is the point when the following is complete: - Practical Completion has been achieved - Final Completion Tests have been completed and passed - All defects and deficiencies have been remediated by the Contractor The defects liability period has expired
Manufacturer / Supplier / Vendor / Original Equipment Manufacturer (OEM)	The entity that manufacturers or supplies equipment to meet the specifications of the Contractor.
Owner / Principal / Seqwater	The entity that engages the Contractor to undertake the work and takes custody of the outcome. The Owner may delegate responsibilities to other entities to act on its behalf (e.g., a consultant).
Practical Completion[1]	The point in which the Solar PV Plant works are complete except for minor commissioning and defects liability period that do not prevent the Plant from being operated for its intended operational purposes
Project Documentation	Documentation related to a particular Solar PV related Project which compliance to this Standard Specification
REX	Seqwater Electronic Document and Records Management System.
Seqwater Approval / Acceptance	Written sign-off gained via the deviation process, as detailed in X-PRO-STD-008 Asset Standards Management and Application.
Shall / must	Indicates a mandatory requirement

[1] General definitions provided for the purposes of this specification, the final Contract shall define these further and are subject to change

Term	Definitions
Should	Indicates a recommendation
Site	The agreed upon specific site selected in the future where the Works will be undertaken
Solar PV Plant	Combined site system with aggregate maximum system capacity
Works	The agreed upon and defined Scope of Works between Seqwater and the Contractor
Trouble-free operation	Absence of significant system failures impacting any overall PV system functionality and operation
Punch List[2]	Document prepared during key milestones or near the close of construction, listing work that the Contractor must complete prior to final payment claim
Final Certificate[2]	Certificate issued upon final completion by the Principal to the Contractor after any outstanding defects are remedied prior to final completion.

4 Abbreviations

The following abbreviations (Table 4-1) apply to this Standard Specification

Table 4-1 – Abbreviations

Abbreviation	Description
AC	Alternating Current
AEP	Average Exceedance Probability
AS/NZS	Australian / New Zealand Standard
ASTM	American Section of the International Association for Testing Materials
ATLM	Audio Tactile Line Marking
BPESC	Best Practice Erosion and Sediment Control
CEC	Clean Energy Council
CT	Current Transformer
DB	Distribution Board
DC	Direct Current
DIN	Deutsches Institut für Normung (German Institute for Standardization)
DLP	Defects Liability Period
DNSP	Distributed Network Service Provider
EDM	Electrical Discharge Machining
ELV	Extra Low Voltage
EMC	Electro-magnetic compatibility
EMI	Electro-magnetic Interference
ESCP	Erosion and Sediment Control Plan
FAT	Factory Acceptance Testing

[2] General definitions provided for the purposes of this specification, the final Contract shall define these further and are subject to change

Abbreviation	Description
FLC	Full Load Current
FOBOT	Fiber Optic Breakout Tray
GHI	Global Horizontal Irradiance
HRC	High Rupture Current
HV	High Voltage (AS3000:2018 definition)
HV	High Voltage
I/O	Inputs/Outputs
IEC	International Electrotechnical Commission
IECA	International Erosion Control Association
IP	Ingress Protection
ISO	International Organization for Standardization
kVAr	Kilovolts Amperes Reactive
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LGC	Large-scale Generation Certificates
LV	Low Voltage (AS/NZS 3000:2018 definition)
MCC	Motor Control Centre
MEN	Multiple Earth Neutral
MET	Meteorological
MPPT	Maximum Power Point Tracking
MVA	Megavolts Amperes
MW_{AC}	Megawatts Alternating Current
MW_{DC}	Megawatts Direct Current
MWp/MWh	Megawatts Peak per Megawatts Hour
NCC	National Construction Code
NER	Neutral Earthing Resistor
NOCT	Nominal Operating Cell Temperature
NTTAs	Non-type-tested assemblies
OEM	Original Equipment Manufacturer
PF	Power Factor
PFC	Power Factor Correction
PFCE	Power Factor Correction Equipment
PID	Potential Induced Degradation
PLC	Programmable Logic Controller
POC	Point of Connection
PPC	Power Plant Controller
PSM	Permanent Survey Marks
PTTAs	Partially type-tested assemblies

Abbreviation	Description
PV	Photovoltaic
PVC	Poly Vinyl Chloride
RCD	Residual Current Devices
RFI	Radio Frequency Interference
RMU	Ring Main Unit
RTD	Resistance Temperature Detector
RTU	Remote Telemetry Unit
SAT	Single Axis Tracking
SCADA	Supervisory Control and Data Acquisition
SLD	Single Line Diagram
SLS	Serviceability Limit State
SPD	Surge Protection Device
STC	Small-scale Technology Certificate
SWMP	or Storm Water Management Plan
THDv	Total Harmonic Distortion (voltage)
TMR	Queensland Transport and Main Roads Department
TTAs	Type Tested Assemblies
UL	Underwriters Laboratories
ULS	Ultimate Limit State
WSAA	Water Services Association of Australia
XLPE	Cross-linked Polyethylene Insulated

5 Reference Documents

The documents listed in Table 5-1 and Table 5-2 and the requirements therein, are relevant to this Standard Specification. In their latest editions, these documents form a part of this Standard Specification. Note that this is not an exhaustive list of documents relevant to the works.

Table 5-1 – Reference Seqwater Documentation

Asset Engineering Standard Document Number	Document Title	Controlled Document Number
	Guidance for Professional Engineering Services at Seqwater	GDE-00242
	Enterprise Risk Management Framework	FRA-00014
	HSW Management System Framework	FRA-00018
	Seqwater Cost Estimating Guidelines	GDE-00041
	WHS, Environment & Heritage – Construction Management Procedure	PRO-00005
	Work Health and Safety Hazard Identification and Risk Management Procedure	PRO-00657

Asset Engineering Standard Document Number	Document Title	Controlled Document Number
	WHS Safe Work with Plant Procedure	PRO-00867
	Corporate Safety – Personal Protective Equipment (PPE) Procedure	PRO-00881
B-SPE-STD-003	Commissioning Requirements Standard Specification	SPE-00346
E-PRO-STD-001	Cable Numbering Convention Procedure	PRO-02389
E-SPE-STD-001	Electrical Design and Construction Standard Specification	SPE-00352
I-SPE-STD-015	Instrumentation	SPE-00353
E-SPE-STD-004	AC Uninterruptable Power Supply (UPS) Standard Specification	SPE-00431
E-TMP-STD-004	Cable Schedule Template	TEM-00283
E-TMP-STD-005	AC Uninterruptable Power Supply (UPS) Datasheet	TEM-00304
E-TMP-STD-006	Conduit and Fittings Datasheet	TEM-00314
I-LST-STD-001	Control Systems Prescribed Equipment List	SPE-00342
I-SPE-STD-005	High Priority Alarms & Interlocks Management Standard Specification	SPE-00356
I-SPE-STD-006	Monitoring and Control System Alarm and Event Management Standard Specification	SPE-00357
I-SPE-STD-009	Control Systems Architecture Standard Specification	SPE-00358
I-SPE-STD-010	Control System Tag Naming Standard Specification	SPE-00359
I-SPE-STD-011	Control System Testing Standard Specification	SPE-00360
I-SPE-STD-013	Control Systems Design and Construction Standard Specification	SPE-00361
I-TMP-STD-003	I/O List Template	TEM-00210
I-TMP-STD-007	Control Systems Test Sheets Template	TEM-00212
I-TMP-STD-008	Master Alarms Template	TEM-00254
I-TMP-STD-014	Instrument List Template	TEM-00148
M-SPE-STD-001	General Mechanical Standard Specification	SPE-00367
M-SPE-STD-002	Fixed Platforms, Walkways, Stairways and Ladders Standard Specification	SPE-00366
M-SPE-STD-004	Protective Coatings Specification	SPE-00348
S-SPE-STD-001	Reservoir - Metal Roof Standard Specification	SPE-00370
X-LST-STD-001	Seqwater Preferred Equipment List	REG-01074
X-PRO-STD-001	Asset Standards Document Classification and Naming Structure	PRO-01873
X-PRO-STD-002	Engineering Drawing Number Procedure	PRO-01872
X-PRO-STD-004	Development and Review of Asset Standards	PRO-01874
X-PRO-STD-006	Equipment Numbering and Naming Convention	PRO-02190
X-PRO-STD-007	Drawing & Spatial Data Standards	PRO-02187
X-PRO-STD-008	Asset Standards Management & Application	PRO-02205
X-PRO-STD-009	Engineering Design, Construction, Operation and Maintenance	PRO-01617
X-PRO-STD-014	Drawings Management Procedure	PRO-02253

Asset Engineering Standard Document Number	Document Title	Controlled Document Number
X-REG-STD-005	Area / Facility Code Register	REG-00996
X-TMP-STD-022	Asset Standards Deviation Request Form	TEM-00224

Table 5-2 – Reference External Standards, Specifications and Codes

Standard/Specification	Document Title
AGPT.6	Austroads Guide to Pavement Technology: Unsealed Pavements
AS / NZS 1170	Structural Design Actions (Part 0 to 2 and 4)
AS / NZS 1768	Lightning Protection
AS / NZS 4509.1	Stand-alone Power Systems Part 1: Safety and Installation
AS / NZS 4777.1	Grid Connection of Energy Systems via Inverters Part 1: Installation Requirements
AS / NZS 5033	Installation and safety requirements for photovoltaic (PV) arrays
AS 1074	Steel tubes and tubulars for ordinary service
AS 1100	Technical drawing, Part 301: Architectural drawing
AS 1111	ISO metric hexagon commercial bolts and screws
AS 1158	Lighting for roads and public spaces
AS 1231	Aluminium and aluminium alloys – anodic oxidation coatings
AS 1243	Voltage transformers for measurement and protection
AS 1289	Methods of testing soil for engineering purposes
AS 1307.2	Surge arresters, Part 2: Metal-oxide surge arresters without gaps for a.c. systems
AS 1319	Safety signs for occupational environment
AS 1429	Electric cables - Polymeric insulated
AS 1554	Structural Steel Welding – Welding of Steel Structures (all parts)
AS 1627	Metal finishing – Preparation and pre-treatment of surfaces
AS 1657	Fixed Platforms, Stairways, Walkways and Ladders
AS 1660	Test methods for electric cables, cords and conductors
AS 1664	Aluminium structures
AS 1665	Welding of aluminium structures
AS 1668	The use of ventilation and air conditioning in buildings
AS 1680	Interior and workplace lighting
AS 1725	Chain link fabrication fencing: Security fences and gates
AS 1891	Industrial fall-arrest systems and devices (all parts)
AS 2067	Substations and high voltage installations exceeding 1 kV a.c.
AS 2159	Piling - Design and installation
AS 2309	Durability of galvanized steel and electrogalvanized zinc coatings for the protection of steel in structural applications - Atmospheric
AS 2312	Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings (part 1 and 2)

Standard/Specification	Document Title
AS 2373:1	Electric cables for control and protection circuits – multi-core control cables
AS 2373:2	Electric cables for control and protection circuits – twisted pair control cables
AS 2423	Coated steel wire fencing products for terrestrial, aquatic and general use
AS 2467	Maintenance of electrical switchgear
AS 2870	Residential slabs and footings
AS 3100	Approval and test specification - General requirements for electrical equipment
AS 3112	Approval and test specification- Plugs and socket-outlets
AS 3191	Electric flexible cords
AS 3566	Self-drilling for the building and construction industries
AS 3600	Concrete Structures
AS 3700	Masonry Structures
AS 3715	Metal Finishing Thermoset powder coating for architectural applications of aluminium and aluminium alloys
AS 3798	Guidelines on earthworks for commercial and residential developments
AS 4086.2	Secondary Batteries for Use with Stand-alone Power Systems, Part 2: Installation and Maintenance.
AS 4100	Steel Structures
AS 4312	Atmospheric corrosivity zones in Australia.
AS 4417	Regulatory compliance mark for electrical and electronic equipment
AS 4488	Industrial rope access systems, Part 1: Specifications
AS 4600	Cold-formed steel structures
AS 4671	Steel for the reinforcement of concrete
AS 4680	Hot dip galvanized (zinc) coatings on fabricated ferrous articles
AS 4702	Polymeric cable protection covers
AS 5000.1	Electric cables –polymeric insulated – for working voltages up to and including 0.6/1 kV
AS 5100	Bridge design
AS 5131	Structural steelwork – Fabrication and erection
AS 5532	Manufacturing requirements for single-point anchor device used for harness-based work at height
AS 60038	Standard Voltages
AS 60076	Power transformers
AS 60137	Insulated bushings for alternating voltages above 1000 V
AS 60146	Semiconductor converters all parts
AS 60529	Degrees of protection provided by enclosures for electrical equipment (IP Code)
AS 60890	A method of temperature-rise assessment by extrapolation for partially type-test assemblies (PTTA) of low-voltage switchgear and controlgear
AS 61558	Safety of Power Transformers, Power Supplies, Reactors and Similar Products
AS 61724	Photovoltaic system performance

Standard/Specification	Document Title
AS 61800.3	Adjustable speed electrical power drive systems - EMC requirements and specific test methods
AS 61869	Instrument Transformers
AS 62052	Electricity metering equipment (AC) – General requirements, tests and test conditions
AS 62053	Electricity metering equipment (AC) – Particular requirements
AS 62271	High-voltage switchgear and controlgear
AS 62368.1	Audio/video, information and communication technology equipment, Part 1: Safety requirements
AS IEC 61800.5.1	Adjustable speed electrical power drive systems-Safety requirements - Electrical, thermal and energy
AS ISO 1000	The international system of units (SI) and its application
AS NZS IEC 62116	Utility-interconnected photovoltaic inverters – Test procedure of islanding prevention measures
AS/ACIF S009:2006	Installation requirements for customer cabling
AS/NZS 1020	The control of undesirable static electricity
AS/NZS 2728	Prefinished / pre-painted sheet metal products for interior/exterior building applications - Performance requirements
AS/NZS 3000	Electrical installations (known as the Australian/New Zealand wiring rules)
AS/NZS 3008.1.1	Electrical installations - Selection of cables - Cables for alternating voltages up to and including 0.6/1 kV - Typical Australian installation conditions
AS/NZS 3013	Electrical installations – Classification of the fire and mechanical performance of wiring system elements.
AS/NZS 3017	Electrical installations - Verification guidelines
AS/NZS 3111	Approval and test specification – Miniature overcurrent circuit breakers
AS/NZS 4024	Safety of Machinery (all parts)
AS/NZS 4506	Metal finishing - Thermoset powder coatings
AS/NZS 4777.2	Grid Connection of Energy Systems via Inverters Part 2: Inverter Requirements
AS/NZS 4836	Safe Working on or near low-voltage electrical installations and equipment
AS/NZS 61000	Electromagnetic compatibility (EMC)
AS/NZS 61439	Low-voltage switchgear and control gear assemblies
AS/NZS IEC 60331	Tests for electric cables under fire conditions – Circuit integrity
AS/NZS IEC 60947	Low-voltage switchgear and controlgear
ASCE7-10	Minimum Design Loads for Buildings and Other Structures
ASCE7-16	Minimum Design Loads and Associated Criteria for Buildings and Other Structures
CEC	GRID -CONNECTED SOLAR PV SYSTEMS: Design guidelines for accredited installers
EN 50380-2003	Datasheet and nameplate information for photovoltaic modules
EN 50461:2006	Solar cells – Datasheet information and product data for crystalline silicon solar cells
HB 100-2000 (CJC4)	Coordination of Power and Telecommunications

Standard/Specification	Document Title
I.S. EN 50530:2010	Overall efficiency of grid connected photovoltaic inverters
IEC 60073	Basic and safety principles for man-machine interface, marking and identification - coding principles for indicators and actuators
IEC 60255	Measuring relays and protection equipment
IEC 60364	Low-voltage electrical installations
IEC 60445	Basic and safety principles for man-machine interface, marking and identification – Identification of Equipment Terminals, Conductor Terminations and conductors
IEC 60715	Dimensions of low-voltage switchgear and control gear – Standardised mounting on rails for mechanical support of switchgear, control gear and accessories
IEC 60865	Short-circuit currents - Calculation of effects
IEC 61215 Ed. 2.0	Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval
IEC 61345 Ed. 1.0	UV test for photovoltaic (PV) modules
IEC 61646 Ed. 2.0	Thin-film terrestrial photovoltaic (PV) modules - Design qualification and type approval
IEC 61730-1 Ed. 1.0	Photovoltaic (PV) module safety qualification – Part 1: Requirements for construction
IEC 61730-2 Ed. 1.0	Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing
IEC 62093	Photovoltaic system power conversion equipment – Design qualification and type approval
IEC 62124 Ed. 1.0	Photovoltaic (PV) stand-alone systems – Design verification
IEC 62443	Industrial communication networks - Network and system security
IEC 62446 Ed. 1.0	Grid connected photovoltaic systems – Minimum requirements for system documentation, commissioning tests and inspection
IEC 62509 Ed. 1.0	Battery charge controllers for photovoltaic systems – Performance and functioning.
IEC 62804	Photovoltaic (PV) modules - Test methods for the detection of potential-induced degradation
IEC 62817	Photovoltaic systems - Design qualification of solar trackers
IEC 62852	Connectors for DC-application in photovoltaic systems - Safety requirements and tests
IEEE 519	Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
ISO 12944	Protective Paint Systems
ISO 14001	Environmental Management System
ISO 45001	Occupational Health and Safety Management
ISO 9001	Quality Management System
ISO 9060	Solar Energy
STNW1174	Standard for Low Voltage Embedded Generating (EG) Connections (Joint Standard Document between ENERGEX and Ergon Energy)
STNW1175	Standard for Connection of Embedded Generating Systems to a Distributor's HV Network (Joint Standard Document between ENERGEX and Ergon Energy)

Standard/Specification	Document Title
UL 2703	Rack Mounting Systems and Clamping Devices for Flat-Plate Photovoltaic Modules and Panels
UL 3703	Outline of Investigation for Solar Trackers

6 Service Conditions

For information regarding the Site Climatic conditions, refer to the E-SPE-STD-001, Electrical Design and Construction Standard Specification. All electrical components related to the Solar PV systems shall be selected and installed to operate under the worst climatic conditions detailed in the - Site Climatic Conditions table of E-SPE-STD-001.

7 General Requirements

7.1 Design Responsibility

The Contractor shall be responsible for all aspects of the design engineering of the PV System including any design required to complete the connection and integration of the PV System.

The Contractor shall be responsible for carrying out any investigation, studies and calculations which are deemed necessary and provide necessary reports to ensure that the PV System and Works comply with the requirements of the Contract.

The PV System shall comply with the requirements of AS/NZS 3000, AS/NZS 5033, AS 4777, AS 60038, STNW1174 (Energy Queensland standard), STNW1175 (Energy Queensland standard), Queensland's Services and Installation Rules (power authority rules), power authority and electricity regulations.

PV Systems which are of less than 100 kW_{DC} aggregate maximum system capacity shall be Clean Energy Council (CEC) compliant and shall be designed and installed to claim STCs. Any system with the capacity that exceeds 100 kW_{DC} shall be considered a power station under Large-scale Renewable Energy Target and shall be eligible for large-scale generation certificates.

Compliance with additional standards is outlined in subsequent sections of this specification and a list of complete standards for compliance required is included in Section 5.

7.2 Laws and Standards

The Contractor is responsible for ensuring that the Works comply with all applicable laws and applicable standards (refer to Section 5), including amendments and revisions from time to time.

All engineering for the Works shall be completed (or directly supervised) by a Registered Professional Engineer(s) of Queensland (RPEQ) based on the discipline of the related works. The RPEQ shall provide sign-off and verification of the Works.

All Solar PV Plant design for small scale systems shall be designed and installed by CEC accredited Contractors. Any accredited large-scale power station shall comply with the requirements under the Renewable Energy (Electricity) Act 2000 and the Renewable Energy (Electricity) Regulations.

The Works shall comply with the specifications, standards, codes, rules and regulations of all statutory authorities having jurisdiction over the works and the best industry practice. This shall include, but not be limited to the latest revision of the following:

a) National Construction Code of Australia

b) Australian (and other) Standards, generally as listed throughout this specification

c) Local Network Service Provider requirements

d) Work Health and Safety Regulation

e) Electrical Safety Act 2002 & Safety Regulation

f) Electrical Safety Codes of Practice

g) Electricity Act 1994 (QLD)

h) Electricity Regulation (QLD)

i) Electricity – National Schedule (Queensland) Act 1997

j) National Electricity (Queensland) Law, as defined in the Electricity – *National Scheme (Queensland) Act 1997*

k) National Electricity Rules as applicable to Queensland

l) National Energy Retail Law (Queensland) Act 2014

m) Telecommunications Act

n) Plant Protection Act 1989

o) Clean Energy Council (CEC) Grid-Connected PV Systems Installation Guidelines

p) Australian Communication and Media Authority

q) Department of Environment and Resource Management – Guidelines

r) Professional Engineers Act 2022

The Contractor shall also comply with the design, installation and maintenance requirements stipulated by the Original Equipment Manufacturer (OEM).

The Contractor shall provide all necessary notices, obtain all permits, perform all tests, and pay all fees and other costs in connection as a part of the Works (as included in the particular Works Specification). On Practical Completion of the system construction, the Contractor shall submit a Certificate of Electrical Safety.

7.3 Design Life and Warranty

Solar PV plants shall have a minimum of 25-year design life considering the impact of the environment in which the plant is constructed in and for the duty specified herein.

Any new building structure pertaining to a solar PV plant shall have a minimum 50-year design life.

The Works shall be designed and constructed to enable continuous operation for the design life requirements. The Contractor shall ensure that all components shall be designed for at least the below requirements.

The design life and Warranty shall not be impacted by the particular site location in which the Solar PV systems is installed.

Table 7-1shows the general minimum requirement for the period of warranty for each equipment in a solar PV plant.

Table 7-1 Warranty Requirements

Item	Warranty term (years)
PV module product (equipment only – no failing)	10
PV module performance (at least 80 % of nameplate rated output)	25
Inverter	10
Structural elements including frames & tracker System	15
Tracker drive and control system	5

As per the table above, the inverters shall have a minimum warranty of 10 years (Extended warranty can be requested/offered by manufacturer during procurement), and the PV modules shall have a 25-year linear performance warranty on power output, such that PV modules generate at least 80% of their nameplate (not minimum) rated output at end of design life (for small scale systems, rated output as measured under Standard Test conditions). Remedy shall be replacement of underperforming modules, or alternatively supply of additional modules to make up the power shortfall during life of the plant.

The PV system, fixings, waterproofing, penetrations, roof access system, and other proposed elements shall be provided with a minimum 10-year warranty in meeting the requirements of the relevant Australian Standards and this Specification for normal operating conditions.

All warranty documentation shall be provided to the principal or nominated representative party (if applicable).

A defect liability period (DLP) of 2 years shall be required from the date of practical completion of work.

7.4 PV Plant Operation

The PV Plant must allow autonomous, remote and safe operation of all systems. The Plant must operate continuously under the Service and Operating Conditions provided (in Section 6 and 7.3 respectively) without shutdown of any part of the system. Some deratings may be allowed at operating temperatures above 35 °C.

Under fault conditions, the affected section of the PV Plant must be automatically and safely isolated allowing the unaffected sections of the Plant to remain operational and to continue to generate and export power to connection point(s).

7.4.1 Operating Conditions

Unless otherwise specified, all electrical equipment and instrumentation will be required to operate continuously for 24 hours per day, 365 days per year under the climatic conditions the equipment is installed into.

7.5 Maintenance and Accessibility

The PV system design shall consider ease of maintenance and accessibility, such that all serviceable items are accessed and maintained safely and efficiently. It is important to allow provisions to perform maintenance without significant dismantling or disruption to other items or parts of the PV system once implemented or unduly curtailing in power generation. In addition, the PV Plant shall allow maintenance activities that can be performed by a limited crew using mobile plant and operating in remote locations.

For ground mount PV systems, the Works shall allow for vegetation management, where applicable, under all equipment including but not limited to cable trays, trackers and combiner boxes.

For rooftop PV Facilities, the design shall allow safe accessibility for maintenance activities by providing adequate clearances and appropriate roof anchor points compliant with AS 1891.4, AS 5532 and AS 4488.

The Contractor shall provide sufficient access around the whole Plant, in accordance with good utility design practice and applicable standards such as Seqwater M-SPE-STD-002 Fixed Platforms, Walkways, Stairways and Ladders Standard Specification, to allow effective maintenance and removal of items or parts thereof and maintain the operation of the PV system unaffected by maintenance tasks.

7.6 Design, Construction, Operation and Maintenance Stage and Review

Generally, the PV Plant shall comply with X-PRO-STD-009 Engineering, Construction, Operation and Maintenance Standard Specification. The requirements of Seqwater X-PRO-STD-009 shall be followed for detailed Seqwater engineering phases and engineering design, review and approval process respectively.

For each stage, allowances shall be included for one design review meeting with the Contractor's designers and Principal. At a minimum there should be allowances made for two rounds of consolidated responses to design review comments from the principal. One for the draft documentation review and the following to review the updated documentation review prior to final issue.

The Contractor is required to revise and resubmit deliverables if they are amended as a result of changes made during the DLP.

7.7 Documentation

For all PV System design, development of all documentation is required. Minimum documentation, review and submission requirements shall be provided as outlined in the relevant Project/Works documentation.

The design documentation shall be issued to the principal for review in consolidated design packages per the engineering design phases indicated in X-PRO-STD-009 Engineering, Construction, Operation and Maintenance Standard Specification.

All documentation shall be written in English and expressed in conventional terms used by engineers and technicians in Australia.

All Deliverables submitted to the principal are to be complete and to have been through the Contractor's own quality review process (at a minimum check, review, verify and approve) as defined in the Contractor's Quality Management Plan.

All documentation in electronic form, produced specifically for the project, shall be in Microsoft Word, Microsoft Excel and Microsoft Project using agreed versions. All other formats require the prior written consent of the principal.

All project drawings produced by the Contractor shall be submitted for Principal's approval and shall comply with Seqwater X-PRO-STD-007 Drawing and Spatial Data Standard, X-PRO-STD-002 Engineering Drawing Number Procedure and X-PRO-STD-014 Drawings Management Procedures.

7.8 Labelling and identification

All Plant labelling shall be engraved multi-layered Traffolyte, compliant with AS/NZS 3000, AS 4777, AS 5033 and AS 5139 in black on white for ID labelling, red on white for warning labelling.

For external cable labels, external labels shall be engraved stainless steel, minimum thickness 1mm.

Traffolyte or similar is acceptable for DC switches, inverters, Solar DB equipment labelling. If labels exceed 1.5 mm thickness, radiused or bevelled edges shall be used.

Where applicable all Plant equipment and materials shall follow the Seqwater X-PRO-STD-006 Equipment Numbering and Naming Convention Procedure (PRO-02190).

7.9 Preliminary Investigations

Prior to any design of Solar PV systems, preliminary investigations shall be undertaken on all relevant existing electrical, civil and structural infrastructure.

The preliminary investigations, which have their baseline requirements further detailed throughout this section of this Specification, shall involve the following at a minimum (but not limited to):

a) Review of any existing documentation provided by the principal including (but not limited to) the following:
   (i) Structural information including drawings
   (ii) Architectural information including drawings
   (iii) Roof access and safety drawings (for rooftop installation)
   (iv) Geotechnical report
   (v) Electrical single line diagrams (SLD)
   (vi) Civil, Structural and Electrical (i.e., Switchboard and switch rooms) General Arrangement and Layout drawings
   (vii) Electrical and Control System Schematic diagrams
   (viii) Control system architecture drawings

b) Undertake a dilapidation survey or condition assessment

c) Conduct a site inspection

d) Develop electrical and structural assessment methodology

e) Assessing the intended Solar PV installation/support structures (e.g., roofing or solar carpark canopy) and investigate any requirement for additional structural materials such as:
   (i) Columns, rafters: mild structural steel.
   (ii) Purlins: mild structural steel, aluminium, or stainless steel.

(iii) Foundations: reinforced concrete

(iv) Access: platforms, stairways, and guardrails

f) Design and develop a preliminary Solar PV system layout, this preliminary layout design shall consider electrical and Solar PV (and other) requirements of this specification, and how best to apply the additional structural loadings (determine whether the existing building structures require modification).

g) Design and develop a preliminary Solar PV energy yield assessment to model the expected generation based on the system location and particulars. The yield assessment shall also consider a standalone non grid connected network.

h) Develop a preliminary civil, structural and electrical design along with preliminary grid connection application for Principal's submission.

i) For behind the meter systems the review shall consider the site load profile, power factor, metering arrangements and expected load changes as specified by the principal.

Note the particular project Works Specifications will detail further requirements for preliminary investigation.

7.9.1 Existing Documentation

The Contractor shall review all existing and relevant civil, structural, and electrical documentation provided by the principal. Where information is incomplete to adequately complete the Works, site inspections and necessary non-destructive investigations shall be nominated and undertaken with Principal's approval to confirm any information gaps, which require rectification in order to complete the Works.

Any discrepancies between on-site arrangements and the existing documentation shall be notified to the principal.

7.9.2 Existing Services

Contractor shall accurately locate of any existing services, including the identification of subsurface services using Principal's As-Built drawings (if available), surveying and 'Dial Before You Dig' prior to design.

If live electrical infrastructure exists in the vicinity during the Works, Contractor should note that the proximity of live electrical and communications equipment will impose restrictions on the way the Works are conducted and shall make due allowance for carrying out work under these conditions.

7.9.3 Dilapidation Survey and Condition Reports

A dilapidation survey or a condition report should be conducted, and a report should be developed for a rooftop or other installations that require the assessment of the existing infrastructures (e.g., carpark canopy installations). This report should summarise the condition of the existing buildings, structure, infrastructure, and findings of the initial investigations as required elsewhere in this specification. A copy of the final report shall be provided to the principal.

This report shall address the following key items as a minimum:

a) The exact specification of roofing material to determine if it would be able to transfer the design weight through the structure to the soil base while not compromising its structural integrity.

b) All existing subsurface elements (i.e., existing services, structures) shall not be adversely loaded by the Works. The site geotechnical report shall be reviewed.

c) Structural adequacy shall be supported by design calculations for all proposed elements of the intended Solar PV installation/support structures, including foundations.

d) Any external roads and drainage infrastructure 500m either side of the proposed main site entrance and alternative access gates (if applicable).

e) The Site including all existing vegetation, infrastructure, waterways and dams and any existing environmental damage or erosion.

Survey may be carried out using mobile laser scanning or physical capture as required. The Dilapidation or condition report will include photographs and schematic drawings that show where existing defects have been identified and shall be presented in a manner that will allow for easy comparison with the post construction condition.

Notwithstanding the above requirements, dilapidation (or similar) surveys as required shall be undertaken as directed by the development approval process (as indicated in the site requirements document). The dilapidation or condition report shall be available to the Principal prior to Site Mobilisation and no Works shall commence until the principal approves the dilapidation report.

7.10 Units and Standardisation

The International System of Units (SI) shall be used, and all items supplied for incorporation in the Works shall be standardised accordingly. If, after making diligent enquiries, the Contractor is unable to obtain an item standardised in SI units, written approval shall be obtained from the principal to supply non-standard material.

SI units shall be used in all correspondence, documentation, calculations, drawings and measurements. If reference must be made to non-standard items, the SI units shall be quoted followed by the non-standard units in brackets.

The Contractor and Subcontractors shall make every effort to standardise mechanical and electrical equipment as well as control systems equipment and instrumentation in compliance with Seqwater Preferred Equipment Lists(s) where applicable.

7.11 Licenses and Software

The provision and implementation of all relevant official release updates to software and firmware shall be included as a part of the Works up to the end of the Defects Liability Period. This should include checks and modifications required to maintain functionality of the Works through any upgrade implementation. Where applicable labelled USB devices containing configuration files for each relevant piece of equipment, to be stored in a secure manner following Principal's instructions.

The licences, software keys, hardware keys (dongles) and the like for all software shall be provided as a part of the Works and throughout the Defects Liability Period. Licences and keys shall not expire and will be on the same terms as specified in the relevant Contract and shall allow the transfer by the principal to any third party at the sole discretion of the principal.

7.12 Design Reliability Target

The target reliability figure for all system design shall be 99% as a minimum for the entire system. If required, a Reliability, Availability, and Maintainability study (RAM) shall be carried out to identify any causes for loss of part of or entire plant. RAM study shall identify the area of vulnerability in which the operation of the plant will be affected so that an appropriate level of redundancy is considered during the design. Particular care should be taken to have no hidden failures, especially for any redundant elements in the design.

7.13 Ingress Protection

The minimum Ingress Protection (IP) rating of switchboards, enclosure, marshalling and junction boxes shall be in accordance with the requirements of Seqwater E-SPE-STD-001 for Electrical Design and Construction Standard Specification.

Inverters and electronics shall be suitable for outdoor installation or be provided with a minimum IP rating of IP65 or be installed inside enclosures with an equivalent IP rating.

Combiner box enclosures shall be rated to a minimum of IP56.

Framing should be designed such that it does not hold water when mounted in any orientation or tilt angle.

All components to be UV resistant and shall be robust enough to handle the Seqwater site climatic conditions specified in E-SPE-STD-001 for Electrical Design and Construction Standard Specification.

7.14 Electromagnetic Compatibility

Compliance shall be provided with AS 61000 and the Australian Communications and Media Authority requirements for electrical and electronics products to meet electromagnetic compatibility (EMC).

Products with C-tick or Regulatory Compliance Mark (RCM) to AS 4417 shall be supplied.

Electrical and electronic apparatus shall comply with AS 61000.6.1: Generic standards - Immunity for residential, commercial and light industrial environments.

8 Technical Requirements

8.1 System Capacity

The aggregate maximum system capacity of a Solar PV system shall be confirmed by the Contractor with the review and approval of the principal at the preliminary design stages of a Solar PV project prior to detailed design.

Generally, the aggregate maximum system capacity should determine the connection voltage level. Provided there are no constraints from the Distributed Network Service Provider (DNSP), systems for grid connection which are less than (but not including) 1.5MW shall be of a Low Voltage (LV) connection (compliant with STNW1174) and systems greater than (and including) 1.5 MW shall be of a High Voltage (HV) connection (compliant with STNW1175).

8.2 Photovoltaic (PV) Requirements

8.2.1 General

Modules shall be fixed to mounting structures depending on the type of Solar PV module support structure i.e., cover rooftop, carpark canopy, ground mount (fixed tilt or single axis tracking). The modules shall be arranged in individual strings and to be connected to inverter units via DC combiner cable boxes.

Depending on the system capacity, site layout, grid connection voltage and power system arrangement, inverters may be individual units (string) or to be integrated into a single Power Conversion Station (PCS).

Notwithstanding the above general description, Solar PV system shall be compliant with AS 3000 and all normative references therein, including but not limited to AS 5033, and any other applicable standards. The Contractor shall determine and be responsible for designing the optimal configuration and layout of the PV arrays.

Any Works conducted in general at a site level, and particularly on top of a roof or working at heights shall comply with relevant safe work procedures, Seqwater safe work methods and procedural requirements.

8.2.2 Modules and Arrays

Modules from Tier 1 manufacturers as per Bloomberg ranking shall be provided. Within the Tier 1 modules, preference shall be given to those modules that have a Positive Quality Rating.

All PV modules making up part of the system shall be of identical make, model and rated power unless otherwise approved by the principal. The PV modules used shall be designed, manufactured and certified in accordance with the following standards:

a) IEC 61215: Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval, if crystalline silicon PV modules are used

b) IEC 61646: Thin-film terrestrial photovoltaic (PV) modules - Design qualification and type approval, if thin-film PV modules are used

c) IEC 61730: Photovoltaic (PV) module safety qualification

The PV module supplier and the facility where the PV modules are manufactured must hold current certification for compliance with ISO 9001, ISO 14001 and ISO 45001.

Certification for the above must be provided to the principal in accordance with a Project Document Schedule (refer to Appendix A)

All modules shall be on the CEC approved modules list. Module installation shall also comply with CEC Grid-Connected PV Systems Installation Guidelines for PV Systems which are of less than 100 kW_{DC} aggregate maximum system capacity.

The PV modules shall comply with Class A of the IEC 61730 standards series or Class II equipment in AS/NZS 3100. Class A modules in IEC 61730-1, IEC 61730-2, EN 61730-1 and EN 61730-2 are considered to meet the requirements for Class II equipment in AS/NZS 3100.

Each PV module must be fitted with a manufacturer's sticker, providing the following information:

a) Manufacturer's name, monogram or symbol of manufacturer

b) PV module type

c) PV module model number

d) Unique serial number and identifying barcode

e) Rated power, current and voltage at maximum power, open circuit voltage and short circuit current (all measured under standard temperature conditions)

f) Polarity of terminals or leads (colour coding is permissible)

g) Date of manufacture

h) Place of Manufacture.

Standard locking connectors (e.g., MC-4 or equivalent) are to be included with the modules. Non-locking connectors are not permitted. Connectors are to be UV resistant for the design life (refer to Section 7.3).

Following installation, the PV module leads shall be properly supported and secured to the frame of the PV module or other support structure and the length of the PV module leads shall be sufficient to allow this. Plastic cable ties shall not be used as the primary means of support for PV module leads. Purpose made stainless steel clips (DKSH or similar) shall be used for the support of the PV module leads.

For bifacial modules (applicable for ground mount systems), string wiring and module to module connectors shall minimise shading the backside of modules.

The Contractor shall be responsible for the removal of damaged PV modules from the Site, during and following Practical Completion until the end of the Defects Liability Period, with respect to sanitary disposal and/or recycling.

For the avoidance of doubt, the principal will not accept any damaged PV modules incorporated as part of the Plant or as Spare Parts upon Final Completion, and Contractor shall procure adequate PV modules to be incorporated into the Plant, to be delivered to the principal as Spare Parts, as well as an adequate allocation of PV modules for shipping and installation damages.

8.2.3 Potential Induced Degradation

The system design shall be done so that it minimises the possible effect of Potential Induced Degradation (PID). Minimisation of PID must be achieved by either:

a) Earthing of the negative (-) end of each string of modules or

b) Providing evidence that modules are certified PID resistant through PID resistance testing from reputable third parties (such as PID Berlin, TUV, or Underwriter Laboratories (UL)) in accordance with the requirements of IEC 62804

c) Other methodology as approved by the principal.

8.2.4 Module Support Structures

The module support structures for the particular Solar PV system may vary and should be determined based on the site-specific conditions and the preliminary investigations in early stages of the Solar PV system design (refer to Section 7.9). The following support structures or a combination of the following can be considered for a Solar PV system design:

a) Rooftop

b) Carpark Canopies

c) Ground Mount – Fixed Tilt (FT) and Single Axis Tracking (SAT)

The PV module support structures shall be designed for the site-specific conditions in accordance with AS 1170. The design of the PV module structures shall be outlined in a civil and structural design documentation submitted to the principal in accordance with a document schedule and shall include wind loading, life assessment, importance levels and means to achieve the correct tilt for the PV module support structures. AS 1170 Importance shall be indicated as a part of the Contractor's Response Schedule (refer to Solar PV Response Schedule Template document).

As part of the design documentation submission evidence by way of calculations to demonstrate that the corrosions protection adequacy to protect the structure for the design life shall be provided.

As far as practicable all dissimilar metals shall be separated to avoid galvanic corrosion.

The PV module support structure manufacturer shall be accredited to ISO 9001 and ISO 14001.

8.2.4.1 Rooftop

Where rooftop PV module support structures are specified in project documentation, it shall meet the following requirements at a minimum:

a) The modules shall be flush mounted and should ideally utilise north facing rooftops where available (subject to confirmation based on the site-specific conditions, roof orientation, slope and based on the preliminary investigation)

b) Modules shall be accessible via rooftop without the need for elevated work platforms. Roof penetrations shall be limited to cabling only, mechanically flushed, and waterproofed, unless it's a microinverter based design

c) Arrays shall be orientated parallel to building elements and be arranged to allow ease of access for cleaning, maintenance and inspections (and detailed in the project O&M manuals) in a safe manner, ideally without warranting structural strengthening of the building (subject to confirmation based on the site-specific conditions and based on the preliminary investigation)

d) Any proposed design shall note the requirements of Work Health and Safety Regulation 2011 and additional procedures and guidelines required by the principal.

e) As far as practicable, PV design shall limit the additional weight introduced to the existing structure

f) The PV design shall provide adequate access for routine 3-monthly roof inspections by the principal

g) For Clear/Treated Water and Reservoirs/Tanks, based on the preliminary investigations (refer to Section 7.9), the PV design and construction shall utilise minimally invasive methods for PV installation on these structures i.e., avoiding penetration to the existing structure, avoiding compromise of the existing structures, etc.

8.2.4.2 Carpark Canopies

Where carpark canopy PV module support structures are specified in project documentation, it shall meet the following requirements at a minimum:

a) Canopies shall utilise available carpark spaces based on the site-specific conditions and the preliminary investigations.

b) Clear height to underside of canopy shall consider a vehicle height of 2.5m to minimise any loss of carparking space, unless directed otherwise in a site requirements document

c) Retaining of all carparking spaces as far as practicable. It is understood that carparks maybe limited during construction and commissioning.

d) Make good any disturbance/damage to the carpark, including but not limited to:

   (i) Sub-surface soil – including maintaining geotechnical properties

   (ii) Carpark surface (i.e., asphalt)

   (iii) Line markings

   (iv) Existing falls/drainage strategy (if present).

e) The design shall consider safety and access to the carpark spaces, including lighting and security if required.

f) Design such that all lighting levels in the carpark is maintained (for servicing the carpark, and pedestrian traffic). As a minimum, lighting levels in all areas shall comply with prevailing local and regulatory safety legislation.

g) Conduct sub-surface locating works to ascertain the presence of any existing sub-surface services, structures or the like.

h) Temporary traffic management provisions shall be provided in liaison with the principal to ensure a minimum required number of carparking spaces available for Principal's requirements e.g., through staging of the construction works, or temporary carparking spaces for the duration of any Works.

8.2.4.3 Ground Mount – Fixed Tilt

Fixed tilt PV module support structure shall meet the following requirements at a minimum:

a) The PV module support structures shall be at least 0.5 m above ground level at their lowest point

b) The structural design of the PV module support structure must be site specific and designed for the Site-specific wind loadings, geotechnical and hydrological conditions and for the design life

c) The structural design shall be in accordance with the structural design requirements outlined in the site-specific Works documentation

d) Site specific structural design certification for the structure as part of the Civil/Structural Design documentation shall be provided and documentary evidence that the PV module support structure, PV modules and any other fixtures to the PV module support structure are protected from damage caused by dynamic wind loading and resonance of the PV module support structure shall be provided

e) All sharp edges are to be avoided or removed, to prevent injury during construction, and to prevent damage to cabling

f) The PV module support structure shall be designed to avoid water and/or moisture accumulation within the structure and will allow water to flow away from the structure

g) The PV module support structure (including piles) shall be provided with corrosion protection able to protect the PV module support structure for the design life (refer to Section 7.3) with no ongoing maintenance required

h) As part of the Civil Design documentation evidence by way of calculations to demonstrate that the corrosion protection adequacy to protect the structure for the design life shall be provided. This shall include reference to and use of Site Conditions including levels of sulphates, chlorides and soil pH.

8.2.4.4 Ground Mount – Single Axis Tracking (SAT)

Where a horizontal Single Axis Tracking (SAT) PV module support system is specified in the Works/project document, it shall meet the following requirements at a minimum:

a) The structural design of the SAT system must be site specific and designed for the site-specific wind loadings, geotechnical and hydrological conditions and for the design life (refer to Section 7.3)

b) The structural design shall be in accordance with the structural design requirements outlined in the site-specific Works documentation

c) Site specific structural design certification for the SAT system as part of the civil and structural design documentation shall be provided and documentary evidence that the SAT system, PV modules and any other fixtures to the SAT system are protected from damage caused by dynamic wind loading and resonance of the SAT shall be provided.

d) All sharp edges are to be avoided or removed, to prevent injury during construction, and to prevent damage to cabling.

e) The SAT system shall be designed to avoid water and/or moisture accumulation within the structure and will allow water to flow away from the structure.

f) The SAT system (including piles) shall be provided with corrosion protection able to protect the SAT system for the design life with no ongoing maintenance required.

g) As part of the Civil Design documentation evidence by way of calculations to demonstrate that the corrosion protection adequacy to protect the structure for the design life shall be provided. This shall include reference to and use of Site Conditions including levels of sulphates, chlorides and soil pH.

h) As far as practicable, all dissimilar metals shall be separated to avoid galvanic corrosion. Details of how this will be achieved will be presented by the Contractor with the Civil Design Report.

i) If the SAT system is required to stow during high wind events in order to meet the design requirements of AS 1170 then the SAT system must be able to automatically stow when high wind events occur based on wind measurements at the MET stations around the site and the SAT system must be provided with an automatic back-up power supply system.

j) If the SAT system is required to stow during flood events in order to prevent submersion of the PV modules, then the SAT must be able to automatically stow when high water levels are detected, and the SAT must be provided with an automatic back-up power supply system.

k) SAT system is required to stow during night-time.

l) Backtracking capability for reduction of module inter-row shading

m) Compliance with the standard listed in Section 8.3.13**Error! Reference source not found.** and 5.

8.3 Electrical Technical Requirements

8.3.1 General

Generally, the Seqwater E-SPE-STD-001 Electrical Design and Construction Standard Specification shall be followed for technical details and specifications of general electrical Design and Construction. This section details the Solar PV system specific electrical technical requirements.

All electrical Works shall be provided by trade certified electricians holding a valid Australian Electrical Work Licence.

Each power conversion station, array, inverter, string, cable, combiner/junction/isolator box must be labelled with a unique identification number based on the Principal's X-PRO-STD-006 Equipment Numbering and Naming Convention Procedure.

AC and DC cabling shall be reticulated on separate cable tray systems and at least 100mm of separation shall be maintained between AC and DC reticulation infrastructure.

Where appropriate PV plant design shall consider spares management as per requirements of Seqwater E-SPE-STD-001 Electrical Design and Construction for aspects such as spare space, installed spare equipment and spare stock. On the AC side of the PV system, appropriate allowances for extra capacity should be considered such as capacity for a spare feeder (in the switchboard) back to the point of connection as deemed appropriate for the particular project requirements.

RPEQ certified Electrical Engineers shall provide the electrical design and certification. All Works are to be in accordance with relevant Codes and Standards, detailed in Section 5.

8.3.2 Standards

Refer to all relevant Seqwater, Australian and International electrical standards indicated Section 5, which are listed for compliance for all Solar PV systems.

8.3.3 Electrical studies

In addition to the requirements of X-PRO-STD-009 Engineering, Construction, Operation and Maintenance Standard Specification, the Contractor shall undertake electrical studies with sufficient detail that is appropriate for the system size and that that cover the following parameters:

a) Arc flash risk

b) Lightning risk

c) Earthing

d) Protection Study and Protection Settings

e) Electrical losses and cable and equipment rating report and calculations and cable schedules.

f) Load flow and fault levels

g) Insulation co-ordination

h) Thermal ventilation

i) Design compliance

8.3.4 Cabling

All DC cabling shall generally follow the specifications of AS 5033. DC cables shall generally be of industrial standard and quality and comply with the requirements listed in Section 8.3.8.5.

All LV AC cabling shall comply with the requirements of Seqwater E-SPE-STD-001 Electrical Design and Construction Standard Specification and AS 3008.1.

Cable installation method shall be determined during the design stage per the particular site requirements. The cables shall follow the route indicated in the project design documentation (this may be indicated in the site requirements and development approval documents) to the connection point.

HV cabling shall be compliant with AS 1429 and in accordance with other applicable standards listed in Section 5.

The cable shall consist single or multicore XLPE cables dictated by the site-specific design. All cables shall be manufactured to Australian standard AS 1429.1. The cable route, conduits and termination design shall comply with AS 2067.

If polymeric cable cover is used for mechanical protection of underground cables, it must comply with AS 4702.

Cable thermal ratings must be calculated in accordance with AS 3008.1.1 or IEC 60287. The cable ratings shall be based on maintaining the conductor temperature below the manufacturer's normal operating temperature under all operating conditions. The designs must pay special attention to cable ratings in accordance with their burial conditions and passage through ducts or in air, and in cases where cables are grouped together or enclosed.

8.3.5 Underground Cable Ways

For underground cable ways specifications refer to requirements of Seqwater E-SPE-STD-001 Electrical Design and Construction Standard Specification.

8.3.6 Marshalling and Junction Boxes

For marshalling and junction boxes specifications refer to the requirements of Seqwater E-SPE-STD-001 Electrical Design and Construction Standard Specification.

8.3.7 Electrical Structures and Fittings

For electrical structures and fitting specifications refer to the requirements of Seqwater E-SPE-STD-001 Electrical Design and Construction Standard.

8.3.7.1 General

AC reticulation shall comply with the relevant standards indicated in Section 5. Cable lengths should be minimised as much as practicable.

All AC cabling provided from the switchboards to the inverters shall be protected by circuit breakers and coordinated accordingly.

Calculations shall be undertaken to size the cabling and circuit breaker selections. Cable sizing calculations shall be done considering the spare power capacities for any future expansions. Calculations shall allow for full circuit breaker loading, and the results shall demonstrate compliance with the following:

j) Voltage drop requirements of AS 3000 and AS 3008. The voltage drop between the sub-mains circuit and individual inverter circuits must not exceed 1%.

k) Voltage drop from the point of supply to the terminals of each inverter shall be less than 2%.

l) Fault loop impedance requirements of AS 3000

m) Current rating of cable in its installed arrangement (considering de-rating factors due to cable bunching and installation techniques) to AS 3008

n) Cascade and discrimination of circuit breakers

These abovementioned calculations shall be provided in a design documentation to the principal.

8.3.7.2 Termination

For termination specifications refer to the requirements of Seqwater E-SPE-STD-001 Electrical Design and Construction Standard Specification.

8.3.7.3 Solar PV Distribution Boards

For light and power distribution boards (DBs) specifications refer to the requirements of Seqwater E-SPE-STD-001 Electrical Design and Construction Standard Specification.

Solar PV DBs shall be designed and manufactured in accordance with the following standards AS 3000, and AS 61439.3.

At a minimum the following information for Solar PV DBs shall be submitted to the principal:

a) Shop drawings.

b) Single line diagram.

c) Fault levels at switchboards.

d) Maximum demand calculations.

e) Cable and conductor cross sectional area and insulation type.

f) Cable operating temperature at design load conditions.

g) Voltage rise calculations

h) Protective device characteristics.

i) Discrimination and grading of protective devices

j) Prospective short circuit current automatic disconnection times.

k) Earth fault loop impedance calculations for testing and verification.

l) Operational and maintenance documentation necessary to operate and maintain the equipment and systems installed

m) Type test certificates for components, functional units and assemblies of the distribution boards

n) Routine tests for electrical and mechanical function tests at the factory using externally connected simulated circuits and equipment.

Solar PV DBs must be constructed in accordance with the following at a minimum:

a) Metallic-coated sheet steel.

b) Main switch/isolator shall be rated at least 125% of nominal current

c) Minimum form 4a according to AS 61439

d) IP rating per the requirements of Seqwater E-SPE-STD-001 Electrical Design and Construction Standard Specification

e) Spare power capacity of outgoing feeders per the requirements of Seqwater E-SPE-STD-001 Electrical Design and Construction Standard Specification

f) For doors enclosing circuit breakers, provide escutcheon plates as barriers between operating mechanisms and live parts.

g) With segregated compartments for metering, control and interface components

h) Factory acceptance testing (FAT) must be carried out and evidence of satisfactory testing submitted to the principal for review

i) Test reports must be submitted to the principal for review

j) Equipped with surge protection device Type II

k) Circuit breakers shall be rated in accordance with inverter manufacturer's recommendations.

l) Cable entry facilities within assembly cable zones for incoming and outgoing power and control cabling.

m) Insect proofing by a non-combustible and corrosion resistant mesh on ventilation openings.

8.3.8 DC System

The DC system shall comprise of above ground and/or below ground DC cabling, combiner/junction/isolation boxes, harnesses and connectors as required.

The DC System shall have the ability to safely be isolated locally, de-energised and locked-out:

a) Each string of PV modules without de-energising other strings and

b) Each Combiner Box (or each string inverter where string inverters are used)

8.3.8.1 General

DC reticulation design shall comply with the relevant standards listed in Section 5.

Calculations shall be undertaken to determine cable sizing. Cables shall be selected to meet short circuit currents, and to minimise voltage drop. The voltage drop between the furthest module and the inverter must not exceed 2% of the total string voltage.

DC cabling shall be sized to minimise voltage drop as specified in AS 5033 as well as being sized for current-carrying and thermal rating.

All DC cabling earthing arrangement shall comply with requirements of AS/NZS 3000.

String voltage shall be calculated based on minimum historical operating temperature. The string voltage shall not exceed 1500V, or the inverter and module limitation, whichever is less.

Inverter loading and DC/AC ratio shall be approved during detailed design phase by the principal.

8.3.8.2 Combiner/Isolation Boxes

If combiner boxes are utilised to combine individual strings of PV modules in parallel,

protection for individual strings shall be provided using touch by finger safe fuse holders in accordance with the requirements of AS 5033.

Combiner/isolation boxes and all associated equipment and components shall be rated for the maximum system voltage and maximum system continuous and short circuit currents. Output shall be able to be disconnected at both poles (the positive (+) and negative (-)) by utilising incorporated disconnect switches.

Combiner/isolation box enclosures shall be IP rated per specifics mentioned in Section 7.13 and have an integral key lock or keyed padlock to prevent access to live terminals. Combiner/isolation box enclosures shall be suitable for exposure to UV for the design life.

Where applicable for bifacial module applications, combiner/isolation shall be mounted on dedicated supports at least 1m away from trackers to the north or south of the end of a tracker row, or to the east or west of fixed tilt racking rows, to avoid module shading.

A DC arc flash study shall be completed by the Contractor.

8.3.8.3 Wiring Harnesses

Where DC wiring harnesses are used, harnesses shall be selected based on the specific cable support structure and the associated cable management system (conduit, cable duct or support channel). Multiple-string harnesses may be used.

The harness cables shall be clipped below modules or onto support structures and laid in a cable duct or support channel and shall be UV resistant if exposed to direct sunlight.

8.3.8.4 String Overcurrent Protection

String overcurrent protection shall be provided in accordance with AS 5033. String protection shall be provided using touch by finger safe fuse holders in accordance with the requirements of AS 5033.

Where DC wiring harnesses are used, the wiring harness shall be provided complete with inline string overcurrent protection i.e., including fuse holders and fuses. If the array is functionally earthed (as per AS 5033), fuses are to be provided in the positive harness only.

8.3.8.5 DC Cables

DC Cabling shall be provided from the module arrays to the inverters, installed in such a way as to minimise losses and prevent Radio Frequency Interference (RFI) loops.

DC cables shall be of industrial standard/quality, and at a minimum shall meet the following specification:

a) Multistrand copper conductors, XLPE insulated, XLPE or TPE sheathed

b) Multicore or single core

c) Rated for the maximum of the highest expected string voltage and 1500V

d) Water resistant, submersible to 5 m

e) Halogen free, low toxicity, flame retardant to AS/NZS 1660

f) Operating temperature range from -40°C to +90°C

g) UV and sunlight resistant

h) Minimum conductor area of 4 mm²

i) Single core cables shall have a black sheath (for negative conductors), and red sheath or black with a red stripe (for positive conductors).

j) Multicore cables should preferably have a black outer sheath. Each inner core (within) shall preferably have a black sheath (for negative) and a red sheath (for positive). If this cannot be offered, provide a 50mm length of black heat shrink (for negative) and red heat shrink (for positive) around the core sheath, adjacent every termination.

8.3.8.6 DC Connectors

All mated DC connectors shall be of the same type and from the same manufacturer. Compatible DC connectors from different manufacturers/models may be used if compatibility tests are provided and approved in writing by the principal.

DC connectors must be equipped with sealing caps to protect them from humidity and dust before connection.

8.3.9 Switchboards

8.3.9.1 General

Generally, for LV Switchboards specifications refer to Seqwater E-SPE-STD-009 Low Voltage Switchboards Standard Specification.

Switchboards shall be compliant of the standards AS 3000 and AS 61439.1.

Following calculations shall be submitted to the principal (in compliance with the standard AS 60890):

a) RPEQ certified calculations verifying switchboard design characteristics.

b) Design calculations of non-type-tested and non-proprietary busbar assemblies

Operational and maintenance documentation necessary to operate and maintain the switchboard, equipment and systems installed shall be provided to the principal

Switchboard testing shall be complaint with the standard AS 61439.1. Routine test results shall be submitted to the principal as follows:

a) Assemblies: Electrical and mechanical routine function tests at the factory using externally connected simulated circuits and equipment.

Non-type-tested assemblies (NTTAs) and Partially type-tested assemblies (PTTAs) routine test as per AS 3000.

The shop drawings at a minimum indicating the following shall be submitted to the principal:

a) Types, model numbers and ratings of assemblies.

b) Design calculations of non-type tested and non-proprietary busbar assemblies.

c) Overall dimensions.

d) Rated current of components.

e) Number of poles and spare capacity.

f) Mounting details.

g) Paint colours and finishes.

h) Access details.

i) Schedule of labels.

j) Component details, functional units and transient protection.

k) Detailed dimensions.

l) Shipping sections, general arrangement, plan view, front elevations and cross-section of each compartment.

m) Projections from the assembly that may affect clearances or inadvertent operation, such as handles, knobs, arcing-fault venting flaps and withdrawable components.

n) Fault level and rated short circuit capacity characteristics.

o) IP rating.

p) Fixing details for floor or wall mounting.

q) Front and back equipment connections and top and bottom cable entries.

r) Door swings.

s) External and internal paint colours and paint systems.

t) Quantity, brand name, type and rating of control and protection equipment.

u) Construction and plinth details, ventilation openings, internal arcing-fault venting and gland plate details.

v) Terminal block layouts and control circuit identification.

w) Single line power and circuit diagrams for all new and modified switchboards.

x) Details of mains and submain routes within assemblies.

y) Busbar arrangements, links and supports, spacing between busbar phases and spacing between assemblies, the enclosure and other equipment and clearances to earthed metals.

z) Dimensions of busbars and interconnecting cables in sufficient detail for calculations to be performed.

aa) Form of separation and details of shrouding of terminals.

bb) Labels and engraving schedules.

8.3.9.2 Switchboard Equipment

Generally, for switchboard equipment specifications refer to the requirements of Seqwater E-SPE-STD-001 Electrical Design and Construction Standard Specification.

Type Test certificates for components, functional units and assemblies shall be submitted unless assemblies have been modified for a custom switchboard arrangement, then equivalent verification to be carried out to meet the minimum requirements. Verification shall be provided whether the particular type tests and internal arcing-fault tests, if any, were carried out at the designated fault currents at rated operational voltage.

Any alterations to type-tested assemblies (TTAs) shall be submitted as records of alterations made to assemblies since the tests.

Switchboard product data shall be submitted to the principal as follows:

a) Makes, types and model numbers of items of equipment.

b) Type test certificates for components, functional units and assemblies including internal arcing-fault tests and factory test data

8.3.10 Inverters

8.3.10.1 General

The type of inverters selected shall be dependent on the site and design specific criteria. The type, make and model of inverter that has been specified in the technical documentation of a specific system shall be used.

DC-AC inverters and grid protection devices (as required) shall be provided to allow injection of power into the either the LV or HV electricity network pending the type of Solar PV system and size.

Inverters shall comply with the following minimum specifications:

a) Inverters shall be selected based on the photovoltaic modules and overall PV system size

b) Inverter DC:AC ratio shall be provided for Principal approval during detailed design

c) Inverter apparent power rating shall be sized to account for reactive power requirements (Power Factor) specified by the principal

d) Inverters shall be compliant with:

  (i) AS 4777 (only required for PV systems connected at LV) and.

  (ii) CEC approved inverters list (only required for systems less than 100 kW_{DC}).

e) Inverters shall have a warranty life specified per Section 7.3.

f) Inverters shall be selected so that it reduces the number inverters required for the PV System and Plant where the most efficient arrangements are designed

g) Inverters shall be compliant with any requirements indicated in the relevant connection agreement.

h) Inverters shall be suitable for outdoor installation or be provided with IP ratings specified per Section 7.13.

i) Inverters shall be able to operate continuously at the environmental design conditions outlined in Section **Error! Reference source not found.** without shutdown of any part of the system. Derating may be allowed at operating temperatures above 35 °C.

j) Inverters shall be provided with appropriately sized protection devices in accordance to AS 4777 and other applicable standards referred to in Section 5.

k) Inverters shall employ a maximum power point tracking (MPPT) scheme to optimise PV module efficiency over the entire range of PV module output under the environmental design conditions

l) Inverters shall be equipped with all hardware for data collection and communication to the communication and control system. DC inputs to the inverter shall have built-in current and fault monitoring for input to the communication and control system

m) The inverter supplier shall be accredited to ISO 9001 and ISO 14001

n) Due consideration shall be given when designing inverter layouts for ventilation, serviceability and exposure to dust and weather. Inverters shall be spaced so as to be readily accessible and serviceable without the need to remove adjacent services. Inverters shall be mounted such that the hot air flow exiting an inverter does not form a significant fraction of the cooling air for any other inverter.

8.3.10.2 String Inverters

String inverter-based PV system design should be given precedence for smaller capacity and/or distributed PV arrangements such as designs for multiple rooftops or combination of rooftops, carpark canopies and/or ground mount systems.

String inverters for decentralised Solar PV systems shall be of three phase transformer-less design.

The string inverters shall operate without shutdown and some derating may be allowed at operating temperatures above 35 °C.

As the PV array string wiring must be fully isolated from ground, the inverters shall provide integral ground fault detection.

As a minimum, string inverters should have front panel enunciation of grid connection and power generation.

These string inverters shall meet the following specification:

a)	Total Harmonic Distortion (PF=1):	No greater than 3.5%
b)	Minimum peak efficiency:	97%
c)	Minimum Euro-efficiency:	96%
d)	Automatic no-load shut down:	Required
e)	DC surge voltage protection:	Integral
f)	Input reverse polarity protection:	Integral
g)	Behaviour on DC overload:	Shift the operating point
h)	Earth fault monitoring:	Integral
i)	DC side switching:	Integral
j)	Maximum Power Point Tracker:	Required
k)	Synchronising with the grid voltage:	Required
l)	Anti-Islanding protection:	Required

m) Over/under voltage and frequency protection settings must adhere to limits specified by the DNSP

8.3.10.3 Centralised Inverters

Centralised inverter-based system design should be given precedence for larger capacity installations where the arrangement is consistent across the same land area i.e., ground mount system or system for a large single rooftop area.

The make and model of centralised inverters used as a basis for any network modelling and obtaining the connection agreements shall be specified in the particular Project documentation (where applicable per NSP requirements). Specified centralised inverters in accordance with the project design documentation shall only be used. The use of any alternate inverter equipment or arrangement shall be approved in writing by the principal. Additional compliance studies associated with the equipment change and non-compliance with any connection agreement is at the expense of the Contractor.

The centralised inverter system shall be designed, and materials shall be equipped in accordance with the latest revisions of applicable sections of relevant Australian Codes and Standards (refer to Section 5).

Inverter voltage, current, and frequency capability shall be selected appropriate for the PV technology used and conditions local to the particular PV Plant and shall have the ability to meet any generator performance requirements under the particular connection agreement sought. The inverter shall be compatible and operate reliably with the Power Plant Controller (PPC) recommended per the project design documentations or any requirements from the DNSP.

These centralised inverters shall meet the following specification:

a) DC input terminations shall have no more than one cable terminated.

b) Each centralised inverter system shall have an appropriate range of self-protection functions to prevent internal damage.

c) Total harmonic voltage distortion (THD) contribution at the Point of Connection (POC) shall comply with the connection agreement.

d) Shall be designed for reliable, trouble-free operation (as defined in Table 3-1)

e) Shall be supplied with the appropriate documentation, including inverter datasheets and certification demonstrating the inverter is compliant with relevant Australian Standards and any other applicable law and standards for use in Australia (refer to Section 5 and 7.2)

f) Shall utilise at least one load-break, 2-pole, lockable disconnect switch for main incoming DC power disconnect for maintenance personnel safety, incorporated either within the inverter housing or separately installed adjacent to the inverter.

g) Inverter output shall be protected by a circuit breaker with short and long time adjustable over current protection.

h) Shall employ a maximum power point tracking (MPPT) scheme to optimize inverter efficiency over the entire range of photovoltaic panel output for the Environmental Design Conditions.

i) Shall be equipped with all hardware for data collection and communication to Principal's central Supervisory Control and Data Acquisition (SCADA) server. Data collection points as described herein shall be integrated into the inverter monitoring and communications package.

j) DC inputs terminated at the inverter shall have built-in current and fault monitoring for input to the SCADA system.

8.3.10.4 Microinverters

Microinverter-based PV system design should be considered for smaller capacity and/or distributed PV arrangements, where areas of shading and fire concerns are persistent in designs for multiple rooftops or combination of rooftops, carpark canopies and/or ground mount systems.

Each PV module shall have its own dedicated microinverter connected as per the microinverter OEM recommended connection and installation methods.

Microinverters for decentralised PV systems can be of single-phase or three-phase transformer-less design. The design shall consist of junction boxes, current transformer, appropriately sized isolators, and distribution boards with communication modules, MCBs and surge protection devices for load and grid connections.

Microinverters supplied and installed at a minimum shall comply with AS 4777 and AS 5033 respectively.

8.3.11 Power Conversion Stations

If central inverters are used, they shall be contained in Power Conversion Stations (PCS). If string inverters are used on sites where step-up transformers are required, PCS shall be used however the inverters may be separate.

The PCS shall include transformer/s to step-up the voltage where necessary. Suitably sized transformer and switchgear shall be provided with associated protection and isolation devices where required.

Each PCS shall be supplied from the same manufacturer. Furthermore, all PCS equipment shall be of the same type, make and model except in the instance where a different size PCS is required to be used for non-standard arrays if required. Equipment contained within each PCS shall be interchangeable with equipment from all of the other PCS.

PCS shall have auxiliary power supply to supply inverter auxiliary loads such as heaters or dehumidifiers (if required to meet manufacturer recommended humidity requirements), lighting, HVAC (if required to meet original equipment manufacturer (OEM) recommended operating temperature requirements), MET Stations and SATs (where these form part of a specific system). Each PCS shall contain a UPS of sufficient size to enable safe shutdown during system low voltage events/outages.

Documentary evidence shall be provided accordingly to demonstrate that the PCS design has been reviewed and certified compliant with relevant Australian Standards.

The make and model of inverters selected for PCS shall be used for network modelling and obtaining particular connection agreement. Additional compliance studies associated with any other make or model of inverters

shall be considered as a non-compliance with the connection agreement and any remediation is at the sole risk and expense of the Contractor providing the Works.

All inverters and transformers selected for PCS shall comply with the specification indicated in Section 8.3.10.3 and 8.3.12 respectively.

8.3.12 PCS Transformers

PCS transformers should be used in centralised PCS incorporated Solar PV systems and based on the site specific and technical design criteria (where the requirements form part of a specific system.

Energy delivered to the Connection point shall be determined based on the voltage (HV) levels. A transformer or transformers shall be provided to step-up the voltage from the PCS inverter output voltage to desired HV and shall meet the following minimum requirements.

Table 8-1 Transformer Requirements

Specification	Requirement
Australian Standard	AS 60076
Maximum Loading at maximum export capacity	95%
Voltage Ratio	As required with HV at 11kV or 6.6kV or 3.3kV
Minimum power efficiency level	As per AS 2374.1.2 (table 1)
Terminal box enclosure rating	IP66
Connections	Palm type in accordance to AS 62271.301

If string inverters are used based on the particular design, the transformer can be incorporated into the same kiosk housing as the HV switchgear without compromising the internal arc flash rating as per AS 62271.200. The secondary (LV) earth fault current should be limited through an earthing resistor if deemed necessary.

Transformer accessories shall include temperature probes, transformer guard, control, protection and earthing terminals. The transformer supplier shall be accredited to ISO 9001 and ISO 14001.

The information of any selected transformers for a PV system design shall be provided in the Seqwater E-TMP-STD-013 Distributed Transformers Datasheet by the Contractor as instructed in the PV Response Schedule document.

8.3.13 Single Axis Trackers

The SAT systems used as a part of a relevant PV plant design (as detailed in Section 8.2.4.4) shall be inclusive of the following:

a) Pre-assembly (if applicable)

b) Mounting and grounding hardware

c) Drive and tracker control system

d) Central controller (if applicable)

e) Integration to the site central control system and SCADA

f) Suitable foundations as per the requirements of Section 8.5

g) Self-powered and not reliant on grid supplied power

The SAT systems provided as part of a PV plant design at a minimum shall comply with the following standards (refer to Section 5 for details of the listed standards below):

a) IEC 62817 – Design qualification of solar trackers

b) UL 3703 – Solar trackers (this is applicable for the SAT structural design as well)

c) UL 2703 – Mounting systems, mounting devices, clamping/retention devices, and grounding lugs for use with flat-plate PV modules and panels

d) IEC 62093 – Design qualification and type approval

e) A third-party structural assessment certificate confirming suitability for Australian applications

The SAT systems provided as part of a PV plant design shall comply with the below requirements at a minimum unless noted otherwise in the particular design documentation:

a) Axial orientation to be North-South

b) Minimum Axis rotation ±45°

c) Average tracking accuracy of ±2°

d) Comply with the design life indicated in Section 7.3

e) DC system voltage of 1500 V

f) Mounting system to be compliant with the PV Module OEM's module installation manual

g) Metal structures shall be integrated with bonding of members such that only a single connection point to the ground grid is required

h) Module mounting hardware shall be integrated with UL 2307 certification or equivalent

i) SAT components shall be suitable for installation and operation in the climatic conditions detailed in E-SPE-STD-001 for Electrical Design and Construction Standard Specification (Site Climatic Conditions).

SAT drive and control system shall be compliant with the following requirements:

a) The SAT drive motor and assembly shall be suitable for outdoor installation with a protection rating of NEMA 3S or IP55

b) Control system shall be suitable for outdoor installation with protection rating of NEMA 4X or IP65

c) Each SAT drive shall be able to individually be monitored and controlled form the PV plant SCADA and monitored form the site central SCADA

d) One or more central controllers connected to Principal's site central SCADA shall be provided via the recommended communications protocol of E-SPE-STD-013 for Control Systems Design and Construction Standard Specification to monitor and control each drive individually

e) SAT monitoring and control systems shall be compatible with the requirements detailed in Section 8.4 and the plant SCADA shall show a summary of the SAT status and key parameters for each central controller

f) SAT drive and control system at a minimum shall monitor the following parameters:

   (i) Axis rotational angle

   (ii) Wind speed and direction (integration to adequate wind sensors for reliable and accurate measurement of local wind conditions as per any minimum anemometer requirement per the project documentation)

   (iii) Drive current.

8.3.14 Protection System

The protection system shall clear faults, so far as is reasonably practicable, without damage to equipment or threat of injury to personnel and quickly identify and isolate faults such that the remaining plant can be safely restored as detailed by the National Electricity Rules and AS 3000. The system shall be designed in accordance with AS/NZS 3000 Clause 2.5.7.

All protection equipment used throughout a system shall be sized and specified to prevent, so far as is reasonably practicable, damage to all components in the event of electrical failure. Any load carrying cables or

PV equipment must also be rated to withstand the maximum fault currents within the plant. The protection equipment must also operate such that it isolates the system from any grid through fault or any fault originated from DC generation system.

The electrical installation shall be designed to provide a reliable supply by selecting protective devices with appropriate discrimination so that in the event of a fault occurring, the fault is isolated and the loss of supply resulting from the operation of a protective device is minimised.

The protection system must grade with the rest of the Seqwater protection system as well as any other relevant upstream protection devices.

The protection system shall include anti-islanding protection at the outgoing system feeder to separate a solar plant from the rest of the Seqwater system during any loss of power in the system it is connected to. The system shall not supply power to the Seqwater systems when it is disconnected from the Grid.

Synchronisation check functionality shall be provided for any points across which it is possible for two non-synchronised sources to exist.

Synchronising capabilities are required for the protection devices to allow the system to reconnect to the network when the Seqwater is re-connected to the Grid and power is restored.

8.3.14.1 Disconnectors

Where outdoor type disconnectors are required as part of the Connection Works, the disconnectors shall be three-pole, outdoor and capable of being manually operated and designed in accordance with AS 62271.102.

Auxiliary contacts shall be provided for remote monitoring and shall be in accordance with AS 62271.

The static and dynamic loadings applicable to the terminals of the disconnector shall be as per IEC 60865-1.

8.3.14.2 Circuit Breakers

8.3.14.2.1 General

The circuit breakers provided shall require minimum maintenance and be compliant with AS 60947 or AS 62271 based on the voltage level.

8.3.14.2.2 LV Circuit Breakers

For LV circuit breaker specifications refer to requirements of Seqwater E-SPE-STD-001 Electrical Design and Construction Standard Specification.

8.3.14.2.3 HV Circuit Breakers

HV circuit breakers shall be fitted with two independent trip coils and shall meet AS 2067 requirements.

The open/close status position of the circuit breaker shall be clearly visible.

HV circuit breakers shall have the ability be remotely operable via the SCADA system (where specific design dictates) and also provide separate OPEN/CLOSE contacts that provide status feedback to SCADA.

Mechanical interlocks are required to prevent operation that cause safety hazards to operators and equipment. E.g., interlocks with the disconnector to prevent operation of the disconnector while the circuit breaker is still closed.

If required in order to prevent any remote operation of the switch a key interlocking system shall be implemented to lock the CB in open while the position of the CB switch is clearly visible.

The mechanical and electrical endurance shall ensure estimated operations within the design life.

The circuit breakers shall be covered by test reports that should be issued to the principal.

8.3.14.3 Surge Arrestors

Surge arrestor design shall comply with AS 1307.2.

An insulation coordination study shall be carried out, if necessary, in accordance with the relevant standards in a HV reticulation system. Selection and rating of surge arrestors shall be in accordance with this insulation coordination study.

For systems spanning across a significant land area (i.e., ground mount systems), surge arrestors should be fitted with either a monitoring system with connection to the SCADA or a surge counter to record the number of significant surges that have occurred.

LV and DC Surge Protection Devices (SPDs) shall be designed and installed as per AS 3000 as applicable.

8.3.14.4 Neutral Earthing Resistors

Neutral Earthing Resistors (NER) shall be sized to limit the fault currents to the currents determined by the earthing and protection studies which shall be undertaken as a part of design.

The temperature limits of the NER shall be within the performance limits for the resistor material, the insulators and the mechanical construction used.

8.3.15 Current Transformers

Current transformer (CTs) shall be designed in accordance with AS 61869.2. The protection CT shall be selected and suitably sized for associated protection functions. Metering CT shall have the minimum required accuracy.

The CT marshalling box shall be equipped with test link terminals with the ability to be shorted as well as being enabled to test all protection and metering equipment without disconnection of any wires from the terminals. Test links shall be labelled to facilitate easy identification.

The earthing location of the secondary circuits of the CTs shall be either at the CT marshalling box or protection/metering panel, depending on the site earthing and test procedure methods. If multiple CTs are required, then the neutrals shall be earthed at the point of summation.

8.3.16 Voltage Transformers

Voltage Transformers (VTs) shall be designed in accordance with AS 1243, AS 60137, AS 3189.1

Each set of VTs shall be equipped with a marshalling box to terminate all VT secondary connections and house all required protection, such as circuit breakers.

The neutral of secondary circuits of all VTs shall be earthed at the VT marshalling box or at the protection/metering panel. Multiple earth points shall not be allowed. VT earthing shall be achieved by a solid connection between the neutral and earth bar.

8.3.17 Earthing and Bonding

8.3.17.1 General

As defined in AS 5033 earthing system design shall be provided as follows:

a) System earthing (electrical earthing)

b) System bonding (protection of exposed conductive parts to mitigate step and touch potential risks)

c) Both earthing systems shall be at the same potential.

Earthing and bonding shall comply with the Electricity Act and the Electrical Safety Act.

The system shall be in accordance with the latest edition and amendments of the relevant Australian and IEC Standards (refer to Section 5). In particular, Solar PV system earthing, and bonding shall comply with following standards:

a) AS/NZS 5033 – Installation of photovoltaic (PV) arrays

b) AS 4777 – Grid connection of energy systems via inverters

c) AS/NZS 3000 – Electrical installations (wiring rules)

d) AS 1768 – Lightning protection

8.3.17.2 Earthing

An earthing study shall be completed and shall be submitted to the principal as a part of the design documentation. The particular Solar PV plant earthing system must clearly and demonstrably ensure the safety of all personnel and equipment under all normal and abnormal operating conditions and all fault conditions that could be reasonably expected. The earthing system must minimise risk of electric shock to persons by ensuring that all calculated transferred potentials, step voltages and touch voltages are within allowable limits set out in applicable standards, including analysis of transferred potential to a location external to the particular site whereby electric shock hazard may be introduced.

The earthing system shall be interconnected, if required as per the earthing design or any applicable standard, with adjacent existing infrastructure, and be tied to the PV module structure and inverter components. These shall be indicated in the relevant new and/or existing drawings.

All fencing, gates, doors, trackers, electrical panels and other similar metallic components must be adequately connected to the earthing system or connected to a separate earthing mat according to the final earthing study and standards specified herein.

An earthing schematic shall be produced for inverter and its associated array.

Fault loop impedance calculations shall be developed and issued for Principal approval. If residual current devices (RCD) are being considered, earth leakage calculations shall be developed and issue for Principal for approval.

A detailed investigation shall be undertaken as a part of the Preliminary investigations into the suitability of the existing infrastructure earthing/bonding and lightning protection system/s to identify any remedial measures to enable the proposed PV system to be safely implemented (if required).

The earthing system shall be designed to satisfy the following criteria:

a) Satisfy the requirements of AS 2067 and AS 3000 and the requirements of the connecting equipment

b) All grounding connections shall be CADWELD exothermic welded connections

c) Guidelines from AS 5033 shall be applied

d) Satisfy the applicable requirements for lightning protection specified in AS 1768

e) Protection clearing time: the longest applicable local or remote backup clearing time

f) Minimum, normal and maximum expected future fault levels at the Connection point over the lifetime of the Solar PV plant, taking into consideration the life of buried conductors and connections having regard to site soil conditions

g) Maximum conductivity to remote earth, low impedance bonding between the Solar PV system earth electrodes and other earth connections, mechanical robustness and high corrosion resistance

h) Surface resistivity: native soil. No corrections for modified surface resistivity due to presence of crushed rock or other layers shall be allowed

All above-ground terminations of the plant earthing system must be marked with unique identifiers in accordance with a scheme that complies with AS 2067, AS 3000 and any requirements of the Principal or the NSP.

All in-ground earthing terminations shall comply with the relevant Australian Standard. Risk of transferred potential through paired cable telecommunications system shall be managed/mitigated in accordance with AS/ACIF Standard S009, HB 100-2000 (CJC4) and any other applicable standards.

The earthing system shall meet on-site commissioning testing requirements in accordance with Section 8 of AS 3000. Standard earthing system testing procedures are outlined in Section 8 of AS 2067.

8.3.17.3 Bonding

All exposed conductive parts shall be bonded to building earth. Un-earthed (double insulated) conductive elements will not be accepted.

Service earthing bar shall be established, and the electrical system earthing shall be connected to the existing infrastructure earthing.

Equipotential bonding cable and terminations shall be provided as required for bonding of exposed conductive elements. This includes bonding of PV modules frames with minimum earth conductor size as required to AS/NZS 5033.

All bonding cables shall have green/yellow insulation. If exposed to the weather, use UV resistant cables, or provide exposed aluminium strap conductors (mounted on the framing).

Details of bonding strategy for all conductive elements of PV system shall be submitted.

8.3.18 Metering

8.3.18.1 General

The metering unit shall be capable of measuring active energy and where appropriate reactive energy. Metering accuracy and installation methods shall be as per the requirements of the National Electricity Rules (NER).

As a general requirement all metering devices within a solar PV system should be capable of being integrated with the building management system (BMS) to provide the remote monitoring on BMS. Metering devices shall also be able to integrate to site control systems and communicate to site SCADA/historian systems.

All the meters within a particular system must be named to reflect the location of the functional unit in any infrastructure. The meter naming convention must be agreed with Principal. All meters must provide at a minimum the real time monitoring of:

a) Phase-neutral voltage (A-N, B-N, C-N).

b) Phase-phase voltage (A-B, B-C, C-A).

c) Phase current (A, B, C).

d) Power (kVA, kW, kVAR - total and all phases).

e) Power factor

f) Energy (kWh and kVARh) for both import and export

g) Frequency

h) Metering accuracy Wh Class 0.5 and Varh Class 2

8.3.18.2 Import/Export and Self-Consumption Metering

Solar PV systems shall include metering to measure the import/export of the site and self-consumption of generated solar energy. The Contractor shall ensure that an import/export meter has been installed (either procured and installed directly by the Contractor or liaising the relevant electricity retailer to upgrade an existing site meter).

The Contractor shall install monitoring hardware as required to allow calculation of self-consumption of generated solar energy.

8.3.18.3 Generation meter

If required as per performance guarantee requirements, a generation meter shall be provided to monitor the total amount of energy generated or consumed by the system. The generation meter shall be located at the PV plant connection point.

Where required, particularly in larger centralised inverter-based systems spanning a large land area, the generation meter shall be via a dedicated panel mounted to the Ring Main Unit (RMU), to prevent unnecessary access to the switchgear. The generation meter panel shall be installed near the main supply circuit breaker, and such that the integrity of the RMU is not compromised

8.3.18.4 Large Scale Generation Certificate (LGC) Meter

Where required for Large Scale Generation Certificates (LGCs), metering of electricity generation for the purposes of LGC generation shall be procured by the Contractor and installed by a metering provider that supplies complete metering kits, including meters, CTs, test blocks, modems, SIM cards and data loggers.

The metering shall be installed as per standard industry practice for revenue metering and shall be commissioned according to the requirements of the supplier. The Contractor shall be completely responsible for ensuring that the metering is correctly configured, is providing accurate and robust measurement and is communicating as required with the metering provider.

Based on the information provided by the metering provider, the Contractor shall inform the principal metering information such as meter serial numbers, details of communication devices, etc. LGC metering shall include remote access to supply the minimum interval data resolution required by Clean Energy Regulator (CER). Generation report shall be configurable and customisable, to allow LGC data to be presented to CER as per any changes required from time to time.

The meter serial number(s) and details of communication devices shall be clearly included on system single line diagrams (SLDs).

The successful commissioning of LGC metering after obtaining CER confirmation/acceptance, and confirmation of the locations of all meters, including the name of the switchboard and the serial numbers of the meter, modem and all inverters metered by that meter shall be communicated to the principal.

8.3.18.5 Power Quality Metering

If required, a fixed type power quality meter shall be supplied, installed, tested, and commissioned.

The device shall be connected to the nominated LV side of the HV transformer for centralised systems. The 3-phase power quality meter shall be capable of at least 1,024 samples per cycle resolution and be equipped with standard industrial protocols for integration into the communications and control system and meet power quality standards IEC 61000-4-30.

8.3.19 Lightning Protection

A lightning risk assessment shall be performed in accordance with AS 1768 for the entirety of Solar PV plant and submitted to the principal. This shall include all possible strike locations, including any site enclosures, fencing and MET station.

Lightning protection study and system shall be provided for all areas of the site in accordance with the recommendations of the lightning risk assessment.

8.3.20 Lighting

Where applicable, permanent artificial lighting shall be provided for any area of the site where equipment is to be operated and maintained at night-time or during the daytime where visibility may be reduced.

Where there are requirements for additional area lighting, whether it be indoor or outdoor, relevant assessment shall be conducted and a lighting system design shall be conducted for construction according to AS 1680 and AS 1158 and any other relevant Australian codes and standards.

Motion sensor driven lighting (which can also be operated manually) should be provided at main site entrance gates as well as at the entrance area to any buildings/infrastructure and at any car park area.

8.3.21 Connection Works

This section specifies the connection works required to enable the generated power by the particular Solar PV plant to deliver to a designated connection point.

The intention of this Specification is not to explicitly specify all elements of the engineering, design and construction necessary to complete the Connection Works. It shall be recognised that the Connection Works must be completed in every respect to enable the particular system to connect to the connection point, to deliver the full output to the connection point and to enable continuous, autonomous, safe, and efficient operation of a system.

The Connection Works shall include the following minimum components:

a) Switchboard(s) for combining the output of inverters and for enabling and isolation and protection of inverters (where there is more than one inverter)

b) Where applicable transformer(s) to step-up inverter output to appropriate connection voltages (i.e., HV in cases involving transformers)

c) Cabling to interconnect inverters, transformers and switchgear

d) Appropriate protection devices to provide protection and isolation of the entire system and connected Seqwater site

e) Generation meter for metering the energy generation and consumption of the Solar PV system

f) Cabling, protection, auxiliary power systems, terminations, enclosures, signage, structures, footings, civil works and all other associated works which are required to enable the Connection Works.

8.4 Communication and Control System Requirements

8.4.1 General

Generally, for communication and control system specifications the following Seqwater Standard specifications shall be referred to and followed:

- I-SPE-STD-013 Control Systems Design and Construction
- I-SPE-STD-009 Control System Architecture
- B-SPE-STD-005 Functional Description Documentation
- I-SPE-STD-006 Monitoring and Control System Alarm and Event Management
- I-LST-STD-001 Control Systems Prescribed Equipment

It should be noted that given most of the abovementioned existing communication and control systems related standards are for water treatment, supply and distribution facilities, certain adaptation and deviations may be required for power generation and distribution of Solar PV systems with Principal's approval.

8.4.2 Control and Monitoring System

A Programmable Logic Controller (PLC) system based on the Seqwater I-LST-STD-001 Control Systems Prescribed Equipment shall be provided to monitor and control Solar PV systems. Other brands of PLC equipment will not be accepted. The PLC shall be supplied with all parts to form a complete system. This will include but not be limited to:

a) PLC processor

b) I/O subsystem i.e., Remote IO etc.

c) Communications subsystem

d) Power supply

e) Panel(s)

The PLC shall interface with all smart devices by bus communications. Fieldbus device interfacing shall be done per the requirements of Seqwater I-SPE-STD-013 Control Systems Design and Construction Standard Specification. This shall include but not be limited to:

a) MET station

b) Each inverter

c) Power quality and generation metering

d) All protection relays (where applicable)

The following list is a non-exhaustive summary of the data to be transferred.

a) Current: maximum, minimum, and average in Amperes (A). In the case of alternating current, it is understood to be the RMS value. It will be measured at the following points:

   (i) Each DC input to each inverter

   (ii) AC output from each inverter

   (iii) Connection point.

   (iv) Each protection relay

   (v) Meters

b) Voltage: maximum, minimum, and average in Volts (V). In the case of alternating voltage, it is understood to be the RMS value. It will be measured at the following points:

   (i) Each DC input to each inverter

   (ii) AC output from each inverter

   (iii) Connection point.

   (iv) Each protection relay

   (v) Meters

   (vi) Batteries

c) Inverter parameters:

   (i) Inverter alarms: Activation / Intervention / Solution (polling each second)

   (ii) Temperature of inverter equipment, in ºC

   (iii) Standard inverter communications parameters

   (iv) Periods without connection to the distribution network, start and end time.

   (v) All parameters that can be received.

d) Temperature of each transformer, in ºC

e) MET station parameters (including irradiance, temperature etc.)

f) All circuit breaker and earth switch statuses

g) All tracking system statuses (where fitted)

The monitoring and control system shall transmit the relevant data from the above indicated and any other information that may be required from smart nodes to the DNSP and AEMO as per the connection agreement(s) (where applicable).

The final tag list must be approved by the principal, clearly indicating which tags are sent to each party.

The PLC shall read values from all the smart devices for the purposes of operating, alarming, diagnostics, maintenance.

Where applicable in appropriate site and design criteria PLCs shall open and close control circuit breakers using comms via the protection relays and shall control the plant as a whole by setting inverter parameters (V, P, Q etc). The control system shall control VARS to assist with achieving designated power factor for the entire site.

If required, the Contractor shall design, supply and install PLC panels complete with all devices and equipment to form a complete system. This would include but not be limited to ethernet switches, Fibre Optic Breakout Tray (FOBOT), power supply, terminals, circuit breakers and labelling. Where panels are located outdoors, they shall meet the weatherproof enclosures per IP ratings specified in Section 7.13. The location of the panels shall be approved by the principal during the design phase of the project.

The PLC panels may be accompanied with door mounted panel view operator interfaces where deemed appropriate i.e., for centralised larger scale systems. This shall be based on a compatible and preferred make and model by the principal. The operator panel shall have keypad and touch screen. This shall be designed, supplied installed and commissioned to show the required status and alarms to an operator using, mimic, trend and alarm pages.

Monitoring shall be provided for the auxiliary device status signals. This monitoring can be by PLC remote I/O or by I/O available on the inverter. The auxiliary device monitoring shall include but not be limited to:

a) HV isolators open and close status (per isolator)

b) Earth switch open and close status (per earth switch)

c) Transformer status signals- Buchholz and overtemperature switches.

PLC application code shall be programmed by System Integrators in Seqwater SOA panel, and the code shall be written with extensive comments to allow third parties to maintain and change the software in the future. The Contractor shall develop a functional description of the application software prior to commencement of coding for approval by the principal (refer to B-SPE-STD-005 Functional Description Documentation). The functional description shall be kept up to date as the project progresses and shall be handed over at the end of the project with comprehensive detail that would allow others to maintain and modify the software.

PLC hardware and software specifications shall be per the requirements of Seqwater I-SPE-STD-013 Control Systems Design and Construction Standard Specification.

Control system diagnostics specifications shall be per the requirements of Seqwater I-SPE-STD-013 Control Systems Design and Construction Standard Specification.

8.4.3 Communication Network

General network communication specifications shall be per the requirements of Seqwater I-SPE-STD-013 Control Systems Design and Construction Standard Specification.

The Contractor shall provide a fibre optic-based communications system to interconnect all smart devices separated by more than 20 meters. The fibre optic cabling specifications shall be per the requirements of Seqwater I-SPE-STD-013 Control Systems Design and Construction Standard Specification. The communications network shall link:

a) Inverters

b) MET station

c) Controller

d) HV Substations (where applicable)

e) Point of connection (feeder) by including a fibre in the appropriate power cable trench route

Smart devices within cubicles or within 20 meters of fibre/switch nodes may be connected with Cat 6E cable which are routed appropriately in cable support structures and/or conduits as required.

The communications system for all communications shall be per a suitable communications protocol specifications per the requirements of Seqwater I-SPE-STD-013 Control Systems Design and Construction Standard Specification.

Generally, the network communications architecture design shall follow the Seqwater I-SPE-STD-009 Control System Architecture Standard Specification. Ethernet switches shall be supplied installed and configured at each inverter and the PLC. Switches shall be per the specific OEM make and model listed in Seqwater I-LST-STD-001 Control Systems Prescribed Equipment. These shall be managed switches and have at least two SFP ports complete with single mode fibre SFP modules for fibre in and out. The MET station fibre end may connect to the comms/control system with fibre to Cat 6E media converters.

8.4.4 Programming Tools

PLC programming specifications shall be per the requirements of Seqwater I-SPE-STD-013 Control Systems Design and Construction Standard Specification.

Where appropriate all programming software and cables for programming all smart devices shall be provided. This shall be complete with all application, programming software for all smart devices. This shall include setting files for protection relays, inverters and other smart devices. This also includes management software for configuration, monitoring, and diagnostics of managed ethernet switches as recommended by the principal's standards.

The scope of devices includes but not limited to:

a) MET station

b) Each inverter

c) Power meters

d) All protection relays

e) Managed switches

f) PLC

g) PLC Panel view operator interface.

All programmable devices shall be supplied with all operating and programming software and licences. These shall be supplied to the principal. All configurable device application configured for the particular system shall be provided in source format to the principal.

All licenced software required for monitoring and diagnostics of smart devices shall also be supplied.

8.4.5 Security

Network security specifications shall be per the requirements of Seqwater I-SPE-STD-013 Control Systems Design and Construction Standard Specification, IEC-62443 and the principal's cyber security requirements specified in the Site Requirements document.

8.4.6 Availability and Redundancy

Availability and redundancy specifications shall be per requirements of Seqwater I-SPE-STD-013 Control Systems Design and Construction Standard Specification.

8.4.7 SCADA System

SCADA system hardware and software specifications shall be per the requirements of Seqwater I-SPE-STD-013 Control Systems Design and Construction Standard Specification.

SCADA graphical design and conventions specification shall be per requirements of Seqwater I-SPE-STD-013 Control Systems Design and Construction Standard Specification.

Overall Plant SCADA representation shall capture all monitoring and control points required with the overall PV plant being illustrated in a main page with sub-pages directing the user from the main page to other parts of the plant areas, which can be drilled down accordingly. PV plant SCADA representation shall be reviewed and approved by the principal.

8.4.8 CCTV Network

In addition to the monitoring and control system, if indicated in the site requirements document as a requirement, a CCTV network should be provided. This is to allow CCTV signals to be accessed by users located at CCTV nodes.

The CCTV network shall use a dedicated set of fibres and shall provide network switches at each relevant CCTV location. The CCTV network shall connect to the site and external network via a router.

8.5 Civil and Structural Technical Requirements

8.5.1 General

The design, supply, installation and certification of all civil and structural elements required shall be provided. This shall include but not limited to:

a) Solar PV System (i.e., PV module support framing, fixings, and connections to the supporting structure, etc)

b) Solar carpark canopies supporting the Solar PV system above the carparks

c) Ground mount supporting structures for fixed tilt and SAT Solar PV systems

d) Modifications (including direct and indirect impacts) to the existing structure or structural systems, which may include the waterproofing system, drainage system, roof access and safety system, protective coatings etc.

e) Penetrations through building elements.

f) Civil works including site surveying, geotechnical studies, soil testing, earthworks, roadwork, drainage works and erosion and sediment control etc.

All buildings and structures shall be designed in accordance with the requirements and recommendations of AS 1170 and AS4100. All loading considerations shall be formulated in accordance with the location of the Site, potential operation and maintenance use and the requirements outlined in AS 1170.

Where applicable all piling shall be designed and constructed in accordance with AS 2159.

All habitable buildings (if required) shall be designed in accordance with the requirements and recommendations of the National Construction Code (NCC).

The importance levels for the general structures shall be outlined in the Site Requirements document.

Certification that the existing civil and structural infrastructure has sufficient reserve design capacity to accommodate the new loadings as per the proposed Solar PV system, without need for strengthening shall be confirmed. If strengthening works are required based on the preliminary investigations the details of the strengthening works shall be indicated to the principal prior to detailed design.

Technical specifications, drawings, engineering calculations, installation guide, warranty information, materials take off, materials of construction, and protection systems (paint, coating, galvanizing, other) and engineering design certificate showing compliance with AS 1170.2, AS 4100 and all other relevant standards and guidelines used shall be provided.

RPEQ certified Civil and Structural Engineers shall provide the civil and structural design and certification. All Works are to be in accordance with relevant Codes and Standards, detailed in Section 5.

The Contractor shall be responsible for the temporary structural stability/adequacy during the works.

8.5.2 Standards

The Works shall be complaint and be performed in accordance with the following latest applicable Standards and Codes including, but not limited to:

- National Construction Code (NCC) of Australia 2019.
- AS 1170 Structural Design Actions: Part 0 General Principles.
- AS 1170 Structural Design Actions: Part 1 Permanent, imposed and other actions.
- AS 1170 Structural Design Actions: Part 2 Wind Actions.
- AS 1170 Structural Design Actions: Part 4 Earthquake Actions.
- AS 4100 Steel Structures.
- AS 4600 Cold-Formed Steel Structures.
- AS 3600 Concrete Structures.
- AS 3700 Masonry Structures.
- AS 1657 Fixed Platforms, Stairways, Walkways and Ladders.
- AS 1664 Aluminium Structures.
- AS 5033 Installation and Safety Requirements for Photovoltaic (PV) Arrays.
- AS 3566.2 Self-drilling for the building and construction industries.
- AS 1554 Structural Steel Welding – Welding of Steel Structures (all parts).
- AS 1627 Metal Finishing – Preparation and Pre-treatment of Surface.
- AS 4312 Atmospheric corrosivity zones in Australia
- AS 2312.1 Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings – Part 1: paint coatings
- AS 2312.2 Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings – Part 2: hot dip galvanizing
- AS 1231 Aluminium and aluminium alloys – anodic oxidation coatings
- AS 1289 Methods of testing soil for engineering purposes
- AS 1725.1 Chain link fabrication fencing: Security fences and gates – General requirements
- AS 2159 Piling – Design and installation
- AS 2309 Durability of galvanized steel and electrogalvanized zinc coatings for the protection of steel in structural applications - Atmospheric
- AS 2423 Coated steel wire fencing products for terrestrial, aquatic and general use
- AS 2870 Residential slabs and footings
- AS 3798 Guidelines on earthworks for commercial and residential developments
- AS 3500.3 Plumbing and drainage, part 3: Stormwater drainage
- AS 5131 Structural steelwork – Fabrication and erection
- AS/NZS 2728 Prefinished / pre-painted sheet metal products for interior/exterior building applications - Performance requirements.

- AS 3715 Metal Finishing Thermoset powder coating for architectural applications of aluminium and aluminium alloys
- AS/NZS 4506 Metal finishing - Thermoset powder coatings.
- AS 1891 Industrial fall-arrest systems and devices (all parts)
- AS 1665 Welding of aluminium structures
- AS 4680 Hot dip galvanized (zinc) coatings on fabricated ferrous articles
- AGPT.6 Austroads Guide to Pavement Technology: Unsealed Pavements

Codes outside the suite of Australian Standards that may be reviewed and adopted as follows:

- ASCE7-16 Minimum Design Loads and Associated Criteria for Buildings and Other Structures
- ASCE7-10 Minimum Design Loads for Buildings and Other Structures

Any standards outside of the Australian suite of standards must be approved by the principal.

The following Seqwater Standard specifications shall be referred to and followed:

- M-SPE-STD-002 Fixed Platforms, Walkways, Stairways and Ladders Standard Specification
- S-SPE-STD-001 Reservoir Metal Roof Standard Specification.

8.5.3 Support Structures

All supporting posts, mounting structures and foundations for the plant shall be suitable for the site climatic and seismic loads, maximum wind speeds recorded in the region and thermal loads caused by expected fluctuations of materials and ambient temperatures. Design shall be in accordance with AS 1170, AS 4100, AS 3600 or any other applicable Australian and International Standard.

All structural components shall be painted, coated, or otherwise protected against corrosion to ensure the supporting structures integrity during the design life. Particular attention shall be paid to the prevention of corrosion at the connections between different metals.

The overall design, structural and foundation design documentation shall contain all design calculations and studies, including but not limited to:

a) Geotechnical soil investigation

b) Site surveying

c) Hydrology/Hydraulics study

d) Design loads study

e) Installation manuals

f) Structural loading calculations

g) Reliability data

h) Compliance report.

8.5.4 Maintenance ot Surrounding Infrastructure

If required, any off-site roads and other infrastructure being used by the Contractor in conducting the Works in as good or better condition shall be maintained as they were in at the start of construction and shall comply with any other relevant conditions for relevant development approvals and dilapidation survey and report requirements detailed in 7.9.3.

8.5.5 Design Loads

Loads shall be determined from the relevant applicable standards. This shall include but not be limited to:

- Allowances for permanent and imposed loads
- Wind loads
- Earthquake loads

Loads shall be determined separately for the structural review for any existing building structures, the design of the solar PV system and the design of the solar carpark canopy structures, as these loads may differ. The extent of loading determination required in the structural assessment methodology shall be clear in the design documentation.

Loads, and subsequent structural design review of structural elements, are to be determined and reviewed in all planes of action (i.e., horizontally and vertically, up and down).

Existing civil and structural documentation which contains information that shall assist in load determinations shall be used. Any site inspections conducted may also assist in load determination and load confirmation.

Permanent Loads

Permanent loads shall be determined in accordance with AS 1170.1.

Gravitational loadings from solar modules, and the corresponding solar PV systems, shall be considered as permanent loads.

8.5.5.1 Imposed Loads

Imposed loads shall be determined in accordance with AS1170.1. This shall include as a provision for any maintenance and construction loadings.

8.5.5.2 Wind Loads

Wind loads shall be determined in accordance with relevant structural standards: NCC BCA and AS 1170.2. Where insufficient guidance is present in AS 1170.2, international standards ASCE7-16 and ASCE7-10 may be reviewed for guidance. Other international standards may also be considered. The use of international standards is subject to review and approval of the principal.

For the structural review of any existing buildings or other structures, an RPEQ certified Structural Engineer shall determine the wind load experienced by any existing building or other structures. This shall be clearly documented as a part of a structural assessment and total wind load experienced shall be documented, which will comprise of (at a minimum):

- Wind load directly experienced by the existing structure (i.e., external and internal pressures)
- Wind load directly experienced by the solar panels (i.e., top surface and soffit surface pressures)
- The interaction of the above wind loads.

8.5.5.3 Earthquake Loads

Earthquake loads shall be determined in accordance with AS 1170.4.

All parts and components shall be designed, detailed and installed to meet the requirements of AS 1170.4. The detailing and design of all connections shall meet these requirements.

8.5.5.4 Load Combinations

Serviceability limit state (SLS) and ultimate limit state (ULS) load combinations shall be determined in accordance with AS 1170.0.

All potential load combinations shall also be considered. A SLS and ULS critical load combination in each practical load direction shall be accounted for, at a minimum.

8.5.6 Importance level

The importance level for the various Solar PV supporting structures shall be provided by the principal and shall be indicated in the Site Requirements document. The Australian Codes and Standards for compliance shall be noted in the Site Requirements document per the determined importance levels as well.

8.5.7 Site Preparation

The Contractor shall be responsible for all survey required to facilitate the Works including, but not limited to, audit surveys, the establishment of Permanent Survey Marks (PSM), setting out of the Works and compliance surveys. All survey shall be undertaken by competent and registered Surveyors.

The Contractor shall be responsible for the preparation of the specific Site required to facilitate the Works including, but not limited to, clearing, and grubbing of vegetation, stripping, and stockpiling of topsoil, construction and/or erection of erosion and sediment control measures, erection of fences and gates or other structures with the approval of the principal.

All clearing and grubbing works shall be performed strictly in accordance with the specific Site development approval. The Contractor shall apply for permission from the local authorities and government departments as required to perform the Works. The extent of clearing and grubbing of vegetation shall be minimised as far as practicable. All felled and cleared material shall be disposed in accordance with at the Contractor's expense considering any of Principal's requirements.

All relevant erosion and sediment control measures shall be erected by the Contractor prior to breaking ground on the specific Site. Refer to Section 8.5.10 for details.

The existing protection of all aboveground and belowground utility services shall be upheld. Where required the demolition, protection and/or relocation of any existing utility services or structures prior to the Works shall be considered, and appropriate approvals or permissions shall be obtained by the Contractor as required in collaboration with Principal.

8.5.8 Earthworks

The Contractor shall be responsible for design, documentation, and construction of the earthworks for the specific Site required to facilitate the Works including, but not limited to, the following:

a) Existing surface testing and treatments

b) Excavations and fill to attain the lines and levels and grades

c) Excavation, bedding and backfill to trenches for belowground utility services and drainage systems

d) Building drainage systems including rainwater harvesting

e) Backfill adjacent to concrete structures as required.

f) Material compliance testing (e.g., material properties, compaction, moisture content)

Specific safety and other measures shall be taken to retain excavation slopes to ensure that structures, equipment, and persons working in or near the excavation are protected.

Earthworks shall be designed as far as practicable to balance cut and fill across the specific Site (i.e., to limit the import or export of fill material).

Any fill material required shall be sourced from on site or off site by the Contractor to meet the criteria. Fill material shall be fit for purpose, and free of deleterious matter, vegetable matter, organic clays or silts, ash, coal, or similar and dispersive soil.

Earthworks shall be sampled and tested to verify that it complies with the standards required (i.e., at a minimum AS 3798). Any sections of the Works that do not meet the standards required when tested shall be reworked and/or replaced as required until it has met the standards required.

Earthworks shall be free draining to prevent the ponding of water.

The Contractor shall be responsible for the disposal of any unsuitable or excess soil, material, or vegetation in accordance with the requirements of the local authorities and government departments. Approval by the Principal shall be obtained for any disposal of material on the specific Site or proximity. No excess material shall be disposed off-site unless approved by the principal. Any material disposed of off-site, and any approvals required shall be at the cost of the Contractor.

The Contractor shall obtain approval by the principal prior to establishing any borrow pits on the specific Site. The Contract Price shall assume that no borrow pits will be opened on the site.

The subgrade beneath footings, buildings and backfill for foundations shall be determined as per AS 1289 and in accordance with any recommendations from the geotechnical assessment.

Cabling trenches shall be backfilled and compacted in accordance with AS 1289 and any requirements of the geotechnical assessment. Additional compaction shall be provided where trenches cross any access tracks.

8.5.9 Roadworks

The Contractor shall be responsible for the design, documentation, and construction of any roadworks required for the specific Site including, but not limited to, the following:

a) Subgrade preparation

b) Flexible pavement including pavement surfacing (e.g., asphalt, seals, unsealed)

c) Rigid (e.g., concrete) pavement

d) Pavement drainage

e) Pavement marking (e.g., Audio Tactile Line Marking (ATLM), line marking, raised pavement markers)

f) Road furniture (e.g., concrete and steel traffic barriers, fencing and gates, grids, road edge guideposts steel beam guardrails, tensioned wire rope barrier systems)

g) Road signage (e.g., direction and information signs, regulatory, warning and hard signs)

Roadworks shall be in accordance with the relevant Australian Standards and guidelines including, but not limited to, Austroads Guide to Road Design, Austroads Guide to Pavement Technology, Queensland Transport and Main Roads (TMR) standard drawings and standard specifications, and the requirements of the relevant local authorities and government departments.

Subgrade conditions shall be based on the outcomes of the geotechnical assessment for the specific Site.

Road geometric design and pavement structural design shall be based on the design traffic loading (i.e., type and volume) as agreed with the principal.

8.5.10 Erosion and Sediment Control

The Contractor shall be responsible for the design, documentation, construction and/or erection of erosion and sediment control measures prior to breaking ground on the specific Site.

Erosion and sediment control measures shall be in accordance with International Erosion Control Association (IECA) Best Practice Erosion and Sediment Control (BPESC) guidelines and standard drawings or other equivalent guidelines as part of Good Industry Practice erosion and sediment control.

The Contractor shall be responsible for the revegetation of any disturbed areas on the specific Site and shall provide temporary measures to ensure the stability of disturbed areas and to prevent erosion and scour prior to revegetation.

Additional protection and special care shall be provided at critical locations within the specific Site, which is inclusive of (but not limited to) drainage outlets, storm water overland flow paths, concentrated water areas, etc.

Particular attention and care shall be considered with dispersive soils located on the specific Site. A suitable action plan shall be included within the Erosion and Sediment Control Plan (ESCP) or Storm Water Management Plan (SWMP), including a site map of known or potential dispersive soils. The ESCP and/or

SWMP shall be updated and resubmitted to all relevant parties if the design or construction intent changes. Associated drawings and ESCs shall also be amended accordingly.

In addition to the requirements provided herein, the Contractor shall also comply with any requirements for erosion and sediment control specified by the specific Site development approval.

8.5.11 Drainage

The Contractor shall be responsible for the design, documentation, and construction of any drainage systems required, and this shall be compliant with the requirements of the specific Sites development approval, local authorities, government departments and Principal. This includes connecting to existing site drainage or construction of a new drainage systems appropriate for the specific Site and design criteria.

The specific Site drainage system shall prevent erosion, scour, ponding and protect the Works from concentrated flows and flooding. The specific Site drainage system shall ensure that there are no adverse impacts to any adjacent (i.e., downstream) sites in comparison to pre-development conditions. Storm water runoff discharged from the specific Site shall follow existing drainage paths as far as practicable with the approval of the principal.

For specific Site drainage systems occupying a large land area for ground mount systems, hydraulic modelling shall be undertaken to demonstrate the specific Site flood conditions.

The Average Exceedance Probability (AEP) for specific Site drainage system and the location, reduced level and freeboard of buildings and critical infrastructure shall be in accordance with the specific Site development approval, latest requirements of the local authorities and government agencies, and the design criteria as agreed with the principal and the necessary stakeholders nominated by the principal.

Erosion and scour protection measures for example concrete, grass, rock protection, grouted rock pitching, level spreaders, etc. shall be used to prevent erosion and scour in and at the outlet of drainage infrastructure including culverts, open channels, drains and swales.

Overland flow paths crossing over access roads may be allowed subject to Principal's approval, where it can be demonstrated that protection measures will be incorporated into the access road to prevent erosion and scour. Where this cannot be demonstrated based on the site conditions, culverts shall be installed to allow runoff to pass under access roads.

8.5.12 Durability

The entire civil and structural systems shall be suitably durable for the specific site location, environment, and design life. Any protective coatings shall be provided (as required) and maintenance recommendations shall be provided to achieve this design life. Protective coatings shall be provided such that no major maintenance is required across the design life.

Durability requirements shall be in accordance with AS 4312, AS 5033 and other relevant Australian Standards.

8.5.13 Concrete Works

Concrete reinforcement shall comply with all applicable Standards including, but not limited to, AS 4671 and AS 3600.

Concrete reinforcement shall be cut and bent in accordance with AS 3600, AS 5100 and/or AS 2870. Welding of grade N or grade W reinforcement is not permitted.

The minimum strength required shall be defined for any concrete or grout forming part of the design.

8.5.14 Footings

Footings shall be designed and installed to suit the loading and geotechnical conditions and shall comply with all applicable standards including, but not limited to the NCC, AS 2159 and AS 3600.

8.5.15 Corrosion Protections

Corrosion protection shall be applied in such a way that all structures can operate for the design life without need for maintenance. Corrosion protection shall be applied as per Seqwater M-SPE-STD-004 Protective Coatings Specification.

The corrosion protection shall be designed as a minimum, in accordance with the requirements of AS 2312 and ISO 12944 and shall account for any specific site conditions and the design life component that corrosion protection is being applied to.

All dissimilar metals shall be separated to avoid galvanic corrosion.

8.5.15.1 Galvanising Work

All galvanising shall be hot dipped galvanising and shall conform with the requirements in AS 2312. Galvanising shall be selected and designed for the design life without maintenance.

The zinc coating shall be smooth, clean, of uniform thickness and free from defects. The preparation for galvanizing and the galvanizing itself shall not adversely affect the mechanical or other properties of the coated material.

All drilling, punching, cutting, bending, welding, filing and machining of parts shall be completed and all burrs, weld splatter or slag shall be removed before the galvanizing process is applied. Surfaces which are in contact with oil shall not be galvanized or cadmium plated.

Threads of bolts, nuts, screwed rods and studs shall not be clogged by surplus zinc.

8.5.16 Maintenance

Maintenance shall be minimal as mentioned in the above individual sections.

8.5.17 Accessibility

Safe accessibility or ways for access shall be provided for all PV module support structures, whether it be rooftop, carpark canopies or ground mount systems.

This shall be determined based on a site-specific basis, if determined in the Preliminary investigations that the site-specific conditions dictate permanent access structures to be required, these shall be provided for ease of maintenance access during the operational life of the PV Plant.

Fall arrestor systems such as anchor points and static lines shall be installed as required based on the site-specific conditions (for rooftop Solar PV, fall arrestor systems shall be installed within 2 meters of the roof line).

8.5.18 Remediation, Rehabilitation and Landscaping

All areas (including temporary hardstand areas, parking and temporary facilities) shall be reinstated which have been disturbed during any construction works by sympathetic landscaping and seeding for appropriate sites and systems. Stabilisation and reinstatement shall be provided to the existing ground cover immediately once earthworks are backfilled and as required for ground stabilisation to prevent erosion and dust. All ground surfaces on site shall be sufficiently uniform and smooth to enable vegetation maintenance (including slashing or mowing) as required post construction works.

Landscaping at the site where this is a requirement of the development approval shall be provided by the Contractor.

Any temporary measures required to prevent erosion prior to revegetation and the removal of all temporary measures following stabilisation shall be provided. Complete stabilisation of all areas of the site and removal is required.

Any works related to a Dam/Catchment area shall follow the special requirements indicated by the principal.

8.6 MET Stations

A MET station shall be provided for all PV systems larger than 500 kW_{AC}. The requirement of the type of MET stations shall be determined (whether to be fully equipped or modular) depending on the size of the plant, location and the area in which the systems span across. For relevant PV systems, the requirement shall also consider the proximity to other MET stations as per AS 61724 and as detailed in the particular works specification and project design documentations.

MET stations shall be located considering the following conditions:

a) At all times there are no reflections or near shading effects on any solar instruments

b) Wind-flow is affected by adjacent structures to a similar extent to the modules

The final location of the MET Station shall be approved by the principal. Calibrations shall be undertaken prior to installation in accordance with applicable standards.

The MET Station structure shall provide secure and stable mounting for the specified instruments, data logging equipment, communications equipment and power supply systems.

Safe access shall be provided for maintenance of all instrumentation.

a) Where a fully equipped MET station is required, this shall include:

- (i) Class A sensors as per AS 61724.1
- (ii) Data logging capability which includes the following characteristics as a minimum:
  - (1) Sampling period: 1 sec
  - (2) Data storage and frequency averaging period: 1 min, 5 min, 10 min, 15 min, 60min (configurable)
  - (3) Storage of the following information for each averaging period: standard deviation, average, minimum and maximum values
  - (4) Independent power supply system including batteries and solar cell and built-in battery charger
  - (5) Ethernet Communications
- (iii) 2 pyranometers in the horizontal plane to measure global horizontal irradiance
- (iv) 1 pyranometers in the plane of the array (multiple pyranometers are required if there are multiple array orientations/tilts)
- (v) Albedo in both the horizontal plane and plane of array (if bifacial modules are utilised)
- (vi) 1 rain gauge
- (vii) 2 probes to measure ambient air temperature with solar shield
- (viii) 2 probes to measure PV module temperature
- (ix) 1 probe to measure ambient relative humidity with protection case.
- (x) Weathervane and anemometer
- (xi) Soiling level
- (xii) Auxiliary input system via connection to the ancillary services network
- (xiii) Communications equipment
- (xiv) Wiring and supports
- (xv) Concrete footing

b) Installations where a fully equipped MET Stations are deemed unnecessary, a modular MET station solution shall be provided with the following inclusions (at a minimum):

(i) Class B sensors as per AS 61724.1

(ii) Data logging capability

(iii) Control system integration

(iv) 1 pyranometer in the horizontal plane to measure global horizontal irradiance

(v) 1 pyranometer in the plane of array (for tracking systems)

(vi) 1 probe to measure ambient air temperature.

8.6.1 Control and Communications System

Refer to Section 8.4.2.

8.6.2 Pyranometers

All pyranometers shall:

a) be suitable for outdoor installation and appropriately protected according to class IP65 or higher

b) shall be installed free of shading effects

For a SAT based system, the POA pyranometer can be mounted on the tracker row frame aligned with the POA and with the ability to follow array rotational direction. The installation documentation shall confirm the orientation being the same as that of the POA.

For horizontally installed pyranometers measuring Global Horizontal Irradiance (GHI), these shall be installed in accordance with the manufacturer's instructions, with installation documentation to confirm the orientation being horizontal. The pyranometers shall be installed such that it is not possible for other objects or structures to shade or reflect light onto the pyranometers, other than any shading that is experienced by other modules such as shading by distance terrain.

All pyranometers shall be deployed with the same cable length used during calibration.

8.6.3 Temperature Measurement

Where required, the ambient temperature shall be measured by two independent air temperature probes provided with solar shields.

8.6.4 Anemometers and Windvanes

All anemometers and vanes shall be high quality, reliable, calibrated cup anemometers.

Anemometers and wind vanes shall be mounted at a height which is representative of the PV modules and free from any abnormal obstruction to wind flow from any direction, i.e., in a location that is similar in exposure to the wind to that of the PV modules. The verticality is to be confirmed and documented.

8.6.5 Enclosure and Cabling

Other than the sensors, all local MET Station system equipment shall be installed in enclosures that meet or exceed an IP 66 rating. All cables shall be in UV rated conduit.

8.7 Temporary Site Construction Facilities

The design, construction, security, operation, maintenance, dismantling and removal of the temporary construction facility or facilities as well as reinstatement and remediation of the area where the temporary construction facility or facilities were located shall be provided. The scale of the temporary construction facility or facilities may alter pending on the scale of the PV system and installations.

The temporary construction facility or facilities shall include the following as a minimum, particularly for larger construction works if no existing amenities can be used:

a) Sufficient car parking and site hut areas to meet requirements of the Contractor, its Subcontractors and the Principal

b) Storage and laydown areas as required to complete the Works

c) Power, lighting and water

d) Telephone and internet access

e) On-site lunch-shed (including general kitchen furniture and storage), drinking water, toilets and first aid facilities and other centralised site facilities as required

f) Provide general maintenance, cleaning and rubbish collection and disposal at the designated site compounds at regular intervals

g) For the Principal's sole use, provide one temporary office to accommodate 4 people, HVAC, telephone, printer and internet service from mobilisation until Practical Completion

For the avoidance of doubt, general consumables (including stationery and computer consumables), computer and printing / scanning hardware, telephones, internet data download / upload and office furniture for use by the Contractor and Subcontractors are included in the Works.

Buildings forming part of the construction compound shall be designed and installed in full compliance with the applicable laws and applicable standards including, but not limited to the National Construction Code (NCC).

Toilets shall be of a type to ensure that all discharges are contained and removed from Site.

The Contractor, with respect to this aspect of the Works, shall be responsible for meeting all applicable requirements in the development approval and obtaining any additional approvals required where the development approval does not allow for the temporary facilities.

8.8 Miscellaneous Requirements

8.8.1 Transport

All necessary transport, labour, works and temporary works necessary for transportation, loading, unloading and erection activities, and entire responsibility for efficient and correct procedures and operations associated with transportation of all components shall be provided at the cost of the Contractor (which shall reflect in the Contractor's scope and pricing to the principal).

All relevant transport facilities, requirements and loading gauges and ensuring that the equipment as packed for transportation conform to any relevant limitations shall be informed to the principal.

Currency of all permits, insurances, licenses, certificates and approvals required in relation the transportation of oversized loads on public roads shall be obtained and ensured by the Contractor.

Steps shall be taken to prevent any offsite or onsite infrastructure such as roads, highways, bridges or overhead lines from being damaged by the Contractor's traffic; and shall select routes, choose and use vehicles, and restrict and distribute loads such that the risk of damage shall be avoided.

Any claims made shall immediately be notified to the principal against it arising out of alleged damage to any off-Site infrastructure, such as highway, bridge, or overhead line. Appropriate procedures shall be in place by the Contractor prior to site mobilisation to ensure all on-Site transportation risks are managed including, but not limited to, transport movement, load lifting, parking, communications, overhead lines, road conditions, steep slopes, speed limits, restricted areas, gates and access routes.

8.8.2 Materials and Suppliers

All materials used shall be new and of the highest quality and of the class most suitable for the purpose specified in this Specification. All materials must be suitable for the design life. No repaired defective parts will be incorporated into without the sanction in writing of the principal.

8.8.3 Vermin protection

The Works shall be suitably protected from all animals that may intrude which could be expected on the site.

Any use of chemical pesticide shall be subject to Principal's approval and the Contractor providing supporting documentation indicating successful compliance with all safety, human contact, livestock contact, and environmental aspects as covered by the laws, permits, approvals, etc. Where applicable, any special requirements indicated by the Principal for Dam catchments areas shall be complied to in regard to vermin protection that may be conducted.

8.8.4 Signage

All on-site and off-site temporary and permanent signs for the direction of construction and operation traffic and for the safety of the works shall be provided. Signs shall be erected when needed, maintained in good condition and removed when no longer needed. All traffic related signage shall be in accordance with applicable laws and applicable standards.

Appropriate signage, fencing and procedures for management of all activities of the Works shall be provided by the Contractor, including all safety related signage, restricted areas (environmental and cultural heritage) requirements and any hazards.

9 Pre-construction Requirements

9.1 Schedule of Manufacturers

Subsequent to the design, prior to construction samples, schedule of equipment manufacturers, equipment, materials, and components shall be submitted to the Principal by the Contractor within the timeframe defined by the Principal from Contract award.

9.2 Product Data

No equipment, martials, components and systems shall be purchased until submissions have been reviewed by the principal and accepted with no exceptions taken.

Manufacturer data shall be submitted for all equipment, materials, components and systems including the following as applicable:

a) Technical specifications/product datasheets

b) Evidence of compliance with specified product certification schemes

c) Drawings, indicating size, arrangement, operating and maintenance clearances

d) Schematic layout, piping, wiring and control drawings

e) Supply Authority approval of grid connected PV system with relevant controls

f) Operating weight and support loadings

g) Lifting points

h) Type test reports

i) Control details

j) Recommendations for installation and maintenance

k) Warranty certificates

l) Structural capacities/testing results

m) Protective coating finishes

9.3 Shop Drawings

Shop drawings, design calculations and samples of prefabricated components such as skids, panels, pits, support structure, etc. shall be submitted to the Principal by the Contractor for approval prior to commencement of construction.

9.4 Pre-construction Tests

Testing and commissioning program which consists of the construction program shall be submitted to the principal. This shall also include particulars of test stages and procedures.

For designated tests, including pre-delivery tests (where applicable), record results and submit reports or certificates in a form suitable for inclusion in operation and maintenance manuals.

9.5 Temporary Construction Power and Water Supply

Temporary power and water requirements for the construction stage shall be detailed in the stages of the design submissions to the principal. This is done to determine whether any site tie-ins are a feasibility or off-site temporary water, and power supplies must be procured to conduct the construction works, in the way of i.e., water tankers, diesel generators, etc.

10 Testing and Commissioning Requirements

For general electrical and control system inspection and testing, Seqwater E-SPE-STD-001 Electrical Design and Construction Standard Specification and all of I-SPE-STD-011 Control System Testing Standard Specification shall be referred to and followed.

The Contractor shall be responsible for conducting, completing and passing all testing outlined herein. Practical Completion Testing shall be completed and passed prior to Practical Completion, while Final Completion Testing shall be completed and passed prior to Final Completion. At a minimum the Contractor shall be responsible for:

a) All required equipment, materials, labour or any other items needed for the testing

b) Packaging, delivery, transport

c) Management of the testing process

d) Rectification and re-testing following any failed testing

e) Performing and passing all testing with sufficient time to avoid any delay to the achievement of Practical Completion or Final Completion

f) Provision of all reports, calibration certificates and documentary evidence required to verify to the principal that all tests have been passed

The following device tests shall be completed on top of the detailed testing in sections from Section **Error! Reference source not found.** onward:

a) Confirm that circuit protective devices are sized, and settings are adjusted to protect installed circuits

b) Calibrate, set and adjust control instruments, control systems and safety controls

c) Arrange for a certified structural engineer to inspect and certify the completed array installation. Undertake the inspection in the presence of a principal nominated Seqwater engineering (or a managerial) representative.

Further in Section 10.3**Error! Reference source not found.** and 10.4, the testing and commissioning requirements for systems less than 500 kW_{AC} and systems larger than 500 kW_{AC} are detailed respectively.

10.1 Notice

Notice shall be given to the principal for witnessing of commissioning tests after commissioning of each system is completed.

10.2 Inspection and Test Records

Inspection and Test Records (ITRs) shall be submitted indicating observations and results of tests and compliance or non-compliance with requirements. These shall be inclusive of dates, commissioning data, test results, protection relay settings for all equipment and systems, with completed checklists.

ITRs examples shall be provided by the Contractor to the principal at the Contract engagement stage, and the format of the ITRs shall be approved by the principal prior to use.

10.3 Simple Testing and Commissioning (for Systems ≤ 500 kW_{AC})

This section applies details the testing and commissioning specifications for systems which are less than 500 kW_{AC} (and inclusive).

Comprehensive electrical tests shall be performed to prove correct operation of the system. All equipment that fails the tests shall be repaired and/or replaced and then re-tested until the tests are passed successfully.

All tests shall be recorded on approved test report forms developed by the Contractor. Where testing involves measurements then actual readings shall be recorded on test report forms.

The Contractor shall submit a test and commissioning schedule at least 7 days before the commencement of testing and commissioning detailing:

a) Date test is proposed for

b) Type of test and details of test

c) Equipment to be tested

d) Test equipment to be used

e) Sample forms for recording of testing.

The principal reserves the right to witness any test. The Contractor shall give written notice of intention to test, not less than 7 days prior to commencing any test.

As a minimum, provide pre-commissioning, commissioning and quality monitoring in exact accordance with the following:

a) Prepare a full commissioning plan including Inspection Test Plan (ITP) schedule to the principal's satisfaction, as part of design submissions. Prior to the submission of the plan, run commissioning workshops (where required) with involvement of the principal and all personnel as necessary to allow all parties to have input during the formation of the commissioning plan.

b) Provide Safety in Design register and safe work procedures to conduct the installation and update the safety in design register during commissioning and with lessons learnt.

c) Where using subcontractors, ensure the Contractor provides a representative during Project commissioning

d) Maximise the use of factory acceptance and other test results to verify the accuracy of the pre-commissioning tests including site acceptance testing where applicable

e) Where required, engage with the equipment manufacturers in the commissioning process,

f) Where required, seek approval from the principal's representatives in the commissioning process

g) Commissioning procedures shall be throughout as outlined in the relevant section of this specification

   (i) Equipment failure during commissioning shall be recorded and an action plan to maintain, repair and prevent similar incidents shall be developed. This includes the operation of systems under failure and fault scenarios, such as failure of mains power

Prior to Practical Completion, ensure all individual systems have been fully commissioned and witness tested to the satisfaction of the principal.

Prior to Practical Completion, at a minimum provide the principal with the following:

a) As constructed drawings, compliant with this specification

b) Testing and commissioning in accordance with AS/NZS 3000 and Category 1 and 2 tests from IEC 62446-1 including, but not limiting to:

   (i) Open circuit voltage measurements

   (ii) Short circuit current

   (iii) Conductivity and insulation tests

   (iv) Infrared scanning of cabling and connections, the modules, isolation points and the inverter

   (v) PV array I-V curve

   (vi) Torque testing results

c) Test and commission the earthing system, (e.g., by 'Safearth' or approved equivalent).

d) Undertake testing and commissioning in accordance with the relevant Australian standard. Submit test results for approval. The testing shall include earth continuity testing of all exposed conductive elements on the PV module support structure. Ensure that every module, its associated framing system, and fixing system is tested for earth continuity.

e) Undertake testing and commissioning in accordance with the DNSP requirement. Submit test results for approval.

f) Where required testing and commissioning of electrical apparatus in accordance with the OEM guidelines and general practice

g) Undertake comprehensive testing of the control system as per the Seqwater I-SPE-STD-011 Control System Testing Standard Undertake tests to demonstrate mechanical integrity and overall assembly of the structural support for PV modules as well as tracking system.

10.4 Practical Completion Tests (for Systems > 500 kW_{AC})

To demonstrate completion and commissioning of a system with an aggregate size of greater than 500 kW_{AC}, two sets of tests shall be carried out. Practical and Final. This section details practical testing and commissioning requirements for these systems and Section 10.5 details the final completion tests.

10.4.1 Practical Completion Test 1 – Verification of Civil Works

The test shall be conducted following completion of all civil, remediation and revegetation Works and when no further heavy vehicle use is expected on the site.

The Contractor shall:

a) Verify that site entrance has not degraded due to the use by the Contractor in performing the Works or that any degradation has been remediated to the satisfaction of the principal

b) Verify that site access roads have been provided to all switching stations, substation, transformers, HV switchgear and central inverters (where central inverters are used)

c) Verify that there is no erosion present on the site. Verify that all slopes and soils have been stabilised to prevent any future erosion.

d) The test shall be passed when all testing is complete, and all identified defects have been rectified and re-tested.

10.4.2 Practical Completion Test 2 – Verification of Structural Works

This testing shall be applied to all PV structures and fasteners making up part of a relevant Solar PV plant being tested unless noted otherwise below.

The Contractor shall:

a) Perform visual verification of the correct installation of the PV module structure for 100% of structures (verticality, module ground clearance and freeboard, alignment according to plan). This procedure to be performed during the installation and recorded on the relevant ITPs

b) At random, verify the correct torquing of fasteners on structures (all fasteners on a minimum of 10% of the structures (including PV module connections) shall be tested). To be performed following complete installation of structures, PV modules, earthing cabling so that all fasteners can be tested

c) Perform visual inspection of the PV module structures for corrosion or damage to galvanising.

The test shall be passed when all testing is complete, and all identified defects have been rectified and re-tested.

10.4.3 Practical Completion Test 3 – Verification of SAT or Fixed PV Module Structure

This test shall be applied to all SATs and fixed PV module structures making up the plant unless noted otherwise below.

The test shall be performed following the complete installation of all SAT or fixed PV module structures and all PV modules and earthing connections to the PV array.

The Contractor shall:

a) Perform pile pull-out tests or any other required tests to the satisfaction of the designer (if required by the geotechnical study or structural designer)

b) Perform visual verification of the correct installation of the footing or pile system for 100% of structures (verticality, module ground clearance and freeboard, alignment according to plan). This procedure to be performed during the installation and recorded on the relevant ITPs.

c) At random, verify the correct torquing of fasteners on structures (all fasteners on a minimum of 10% of the frame (including PV module clamp and earthing connections) shall be tested)

d) Perform visual inspection for corrosion or damage to galvanising.

The test shall be passed when all testing is complete, and all identified Defects have been rectified and re-tested. The Contractor shall provide a test report outlining the test methodology and evidence demonstrating compliance with test acceptance criteria.

10.4.4 Practical Completion Test 4 – Verification of MET Stations

The test shall be performed following completion of the MET station per the Solar PV plant being tested (where applicable) and when the data from the MET station is being sent to the SCADA system.

The Contractor shall:

e) Verify that all MET station equipment includes up to date calibration certificates for the configuration for which they were installed

f) Verify proper mechanical installation of sensors and monitoring equipment

g) Verify that all equipment is in the proper location and that it is properly connected. Place special emphasis on equipment accessibility for proper maintenance

h) Verify that equipment is not obstructed by any element, with special attention given to shadow or reflection on the pyranometers. Pyranometers shall be placed such that there is no shading or reflection from other structures.

i) Verify the validity of data collected and check to ensure there are no erroneous values or discrepancies. Check sensors and data logger calibration sheets and correct input settings.

j) Verify operation of back-up power supply.

The test shall be passed when all testing is complete, and all identified defects have been rectified and re-tested.

10.4.5 Practical Completion Test 5 – Verification of Communications and Control Systems

Generally, comprehensive testing of the control system as per the Seqwater I-SPE-STD-011 Control System Testing Standard Specification shall be undertaken.

The Solar PV plant being tested must be operational and delivering electricity to the connection point prior to commencing the test.

The Contractor shall verify that all required data (inclusive of all field signals as well as protection, CBs, etc.) is able to be received by the SCADA system.

The test shall be passed when all testing is complete, and all identified defects have been rectified and re-tested.

10.4.6 Practical Completion Test 6 – Verification of DC/AC Cabling

This test shall be applied to all DC/AC cabling and PV module leads in Solar PV plant being tested.

This test shall be undertaken following the complete installation of all DC/AC cabling and the complete installation of all cable supports and protection.

The Contractor shall:

a) Verify that excessive bending radius and tension applied to cabling has been avoided. Verify that all cabling (and supports) is fastened to structural elements so that stability is ensured at all times

b) Verify that no cables or sections of cables are dangling or unsupported

c) Verify that all cable sections are fastened and in good condition with no damage. Verify that there are no sharp edges that may damage the cabling

d) Verify that all transitions (including above ground to below ground cabling and above ground transitions) are correctly fastened to the structural elements using weather resistant joint elements and are protected from mechanical damage

e) Verify that all underground cabling has been installed according to the design and in accordance with all applicable standards (to be completed during the installation process and recorded on ITPs).

The test shall be passed when all testing is complete, and all identified defects have been rectified and re-tested.

10.4.7 Practical Completion Test 7 – DC/AC Cable Insulation Testing

This test shall cover all DC cable between PV strings and inverters and AC cable between inverter(s) and AC switchgears. The DC cable testing procedure will be performed once all the DC circuits have been completed.

a) The Contractor shall perform a visual inspection of all accessible cabling and:

   (i) Check the cabling for proper condition

   (ii) Ensure there are no shredding, splices or repairs with insulating tape or any other improper elements

Following the visual checks, the Contractor shall perform the Insulation Resistance (IR) test procedure according to the standard AS 3017 and IEC 60364-6.

b) The test shall be passed once all of the cabling under test meets the following requirements:

   (i) The cabling is in good condition and the cable resistance of the test shows insulation greater or equal to 1MΩ and in accordance with AS 3017

   (ii) The cabling complies with all other criteria in applicable standards

   (iii) All faulty sections found have been replaced.

10.4.8 Practical Completion Test 8 – Earthing Resistance Test

Testing shall only be undertaken when the earthing system is complete.

The Contractor shall:

a) Perform a visual inspection of all accessible earth cabling. Check earth cabling for condition. Ensure there are no slices or repairs with insulating tape or any other improper elements.

b) Verify that all metallic elements (including all cable tray sections) are connected to the earthing system by a fastener, terminal or by the electrical continuity of the structure.

c) Continuity tests of earthing connections

d) Carry out current injection testing of the earth grid to verify the installation against the design including:

   (i) Earth grid combined impedance

   (ii) Earth potential rise measurement

   (iii) Current distribution

   (iv) Transfer, step and touch potential testing.

The above tests are to be carried out in accordance with AS 3000 and AS 2067. The test results are to be recorded and provided to the designer to review. The test will be passed if the installation is within the design requirements.

10.4.9 Practical Completion Test 9 – Category 1 tests from IEC 62446-1

All strings of PV modules within the particular Solar PV plant shall be subject to this test. The test may commence once the PV modules under test are installed and connected in series back to the combiner box/inverter.

The test shall verify:

a) The polarity of strings by following the procedures specified in IEC 62446-1:2016 Section 6.2.

b) The open circuit voltage of the strings in accordance with the requirements of IEC 62446-1:2016 Section 6.4, or alternatively an I-V curve test may be performed in accordance with IEC 62446-1:2016 Section 7.2.

c) The short circuit current of the strings in accordance with the requirements of IEC 62446-1:2016 Section 6.5, or alternatively an I-V curve test may be performed in accordance with IEC 62446-1:2016 Section 7.2.

The test will be passed when:

a) The polarity of all strings has been shown to be correct.

b) The measured open circuit voltage of the measured strings shall be compared to the expected V_{oc} derived from the datasheet and maximum allowable DC voltage. The string open circuit voltage measured shall be at least 95% of the expected minimum value and less than the maximum. Any strings exhibiting voltage outside the allowable range shall be rectified and the test re-performed.

c) The current measurements for individual strings must be within 5% of the average (or expected) string current.

The Contractor shall provide a test report outlining the test methodology and evidence demonstrating compliance with test acceptance criteria.

10.4.10 Practical Completion Test 10 – IV Curve Test

All strings of PV modules within the particular Solar PV plant shall be subject to this test. The test may commence once the PV modules under test are installed and connected in series back to the combiner box/inverter.

IV Curve measurements shall be performed in accordance with IEC 62446-1:2016 Section 7.2.

The Contractor shall provide a test report outlining the test methodology and evidence demonstrating compliance with test acceptance criteria.

10.4.11 Practical Completion Test 11 – Thermography of Electrical Connections

10.4.11.1 Scope

This procedure shall be performed for:

a) 100% of combiner boxes/DC isolation boxes

b) All transformers

c) All inverters

d) All switchboards

e) All distribution boards

f) All other accessible electrical connections including those forming part of the Connection Works

PV module lead connections are exempt from this test.

10.4.11.2 Commencement Requirements

The test must be undertaken when the following conditions are all met:

a) The PV Plant is operational, and the PV modules are connected

b) The test shall be conducted on a sunny day with stable global horizontal irradiance greater than 600 W/m²

c) The tests shall only be performed once the MET stations are operational

d) The MET Stations (if applicable) shall be used to verify the global irradiance at the time of testing. The electrical connections under test must be electrically loaded.

10.4.11.3 Performance of the Procedure

A thermographic camera is required to conduct this test. The Contractor shall:

a) Visually verify that all cable has been laid in an orderly manner. Ensure the distance from active elements is correct and that all phases are connected properly

b) Verify that the cables do not have an excessive amount of wire showing (>5 mm)

c) Verify that metal masses are properly connected to earth. Verify there is adequate physical protection for live electrical equipment and ensure that there is separation between them and grounded metal masses

d) Verify that cables are properly connected to the terminal block, connectors, current transformers, switchgear, meters and all other elements

e) Take a thermal image of all accessible electrical connections at the Plant (with the exception of PV module connections) to verify the proper condition of connections and to detect hot spots.

10.4.11.4 Acceptance criteria and Deliverables

Compliance with the following is required for acceptance of the procedure:

a) Procedures a) – e) above have been complete and any Defects identified have been remediated.

b) There are no hot spots at connections, terminal points or cables. A hot spot is defined as a point where the temperature is noticeably greater than the expected temperature during normal operation and compared to its surroundings.

c) The temperature difference between similar or adjacent electrical connections shall not be greater than 10%. Where the temperature difference is greater than 10% the joint/connection shall be corrected and re-tested

The Contractor shall provide a test report outlining the test methodology and evidence demonstrating compliance with test acceptance criteria providing photos of electrical connections.

10.4.12 Practical Completion Test 12 – Inverter Testing

All inverters in the PV plant shall be subject to this test. The Contractor shall conduct testing of the inverter as per AS 4777.2 requirements (or equivalent international standard as per OEM instructions) and/or recommended by the inverter OEM and connection requirements. Also, any tests required for maintenance of the inverter warranty (as per OEM manual such as thermographic inspections, fan inspections, filter checks, etc.) shall be conducted.

As required request OEM specialist's support shall be sought by the Contractor for certain tests i.e., for centralised inverters. All inverter testing must demonstrate compliance with the requirements of the inverter supplier and with the inverter data sheet.

10.4.13 Practical Completion Test 13 – Visual Inspections of the PV Modules

This test shall be applied to all PV modules in the particular PV plant being tested:

a) Following the complete mechanical and electrical installation, the Contractor shall perform a thorough visual inspection of each module for the following defects, as well as inspecting or any other non-compliances with the manufacturer's specifications:

(i) Cracked, bent, misaligned or torn external surfaces

(ii) Broken cells

(iii) Cracked cells

(iv) Faulty interconnections or joints

(v) Cells touching one another or the frame

(vi) Failure of adhesive bonds

(vii) Bubbles or delamination forming a continuous path between a cell and the edge of the module

(viii) Tacky surfaces of plastic materials

(ix) Faulty terminations, exposed live electrical parts

(x) Any other conditions which may affect performance.

The nature and position of any cracks, bubbles or delamination etc. which may worsen and adversely affect the module performance in subsequent tests shall be noted and/or photographed.

For defects not explicitly stated above, the Contractor shall determine the root cause and potential present and future impact and submit the findings to Principal for review. If it is determined that the defect affects or will affect production or the integrity of the PV module, it will be considered a reason for rejection.

b) During the inspection, for any identified defect, the following shall be recorded:

(i) Position

(ii) PV module serial number

(iii) Description of the defect observed

(iv) Date of detection of the defect

(v) Hyperlink to a photograph showing the defect.

c) Compliance with the following is required for passing the test:

(i) All PV modules in the particular PC plant being tested have been inspected in accordance with the test procedure and any PV modules determined to be defective under the test have been replaced with new PV modules

(ii) Replacement PV modules have been inspected in accordance with the test procedure and have been found defect free.

10.4.14 Practical Completion Test 14 – Installed Capacity Guarantees

This test shall occur following the complete installation of all PV modules at the particular Solar PV plant being tested.

The Contractor shall provide flash test (or sun simulator test) results for each PV module making up part of the plant including spares and compare with OEM tests results provided. The flash test results shall be used to calculate the rated power for PV modules for the purpose of the installed capacity guarantee. Bifacial gain shall not be used in this calculation.

The Installed DC Capacity shall be equal to the sum of the rated power under Standard Test Conditions of all PV modules installed at the particular Solar PV plant according to flash testing and delivering power to the connection point.

The Installed AC Capacity shall be equal to the sum of the rated AC output power of all inverters installed at the particular Solar PV plant being tested.

The Guaranteed DC Capacity shall be defined within the design documentation i.e., Technical Schedules.

The Guaranteed AC Capacity is defined within the design documentation i.e., Technical Schedules.

a) For the test to be passed the following must hold true

(i) The Installed DC Capacity must be equal to or greater than the Guaranteed DC Capacity.

(ii) The Installed AC Capacity must be equal to or greater than the Guaranteed AC Capacity.

10.5 Final Completion Tests (for Systems > 500 kW_{AC})

This section details final testing and commissioning requirements for systems which are larger than 500 kW_{AC}.

10.5.1 Final Completion Test 1 – Verification of Civil Works

This test shall be applied to the entirety of the particular Solar PV plant being tested and the site.

The Contractor shall:

a) Verify that there is no erosion present on the site. Verify that all slopes and soils have been stabilised by permanent vegetation (70% regrowth) to prevent any future erosion. For this test, temporary erosion and sediment controls such as sedimentation fences are insufficient

b) Verify that all temporary sediment and erosion control devices have been removed

The test shall be passed when all testing is complete, and all identified defects have been rectified and re-tested.

10.5.2 Final Completion Test 2 – Verification of Structural Works

This testing shall be applied to all PV structures and fasteners making up part of the particular Solar PV plant being tested unless noted otherwise below.

The Contractor shall:

a) At random, verify the correct torquing of fasteners on structures (all fasteners on a minimum of 10% of the structures (including PV module connections) shall be tested).

b) Perform visual inspection of the PV module structures for rust or damage to galvanising

The test shall be passed when all testing is complete, and all identified defects have been rectified and re-tested.

10.5.3 Final Completion Test 3 – Visual Inspection of the PV Modules

This test shall be applied to all PV modules in the particular Solar PV plant being tested.

Visual inspection shall only commence once PV modules are fastened to the structure and are electrically connected and all earthing, cable tray and other equipment attached to the PV structures have been installed and torqued.

a) Following the complete mechanical and electrical installation, the Contractor shall perform a thorough visual inspection of each module for the following defects, as well as inspecting or any other non-compliances with the manufacturer's specifications:

    (i) Cracked, bent, misaligned or torn external surfaces

    (ii) Broken cells

    (iii) Cracked cells.

    (iv) Faulty interconnections or joints

    (v) Cells touching one another or the frame

    (vi) Failure of adhesive bonds

    (vii) Bubbles or delamination forming a continuous path between a cell and the edge of the module

    (viii) Tacky surfaces of plastic materials

    (ix) Faulty terminations, exposed live electrical parts

    (x) Any other conditions which may affect performance.

b) The nature and position of any cracks, bubbles or delamination etc. which may worsen and adversely affect the module performance in subsequent tests shall be noted and/or photographed.

c) For defects not explicitly stated above, the Contractor shall determine the cause and potential present and future impact and submit the findings to Principal for review. If it is determined that the defect affects or will affect production or the integrity of the PV module, it will be considered a reason for rejection.

d) During the inspection, for any identified defect, the following shall be recorded:

(i) Position

(ii) PV module serial number

(iii) Description of the defect observed (if any)

(iv) Date of detection of the defect

(v) Hyperlink to a photograph or image itself showing the defect

10.5.3.1 Acceptance Criteria

Compliance with the following is required for passing the test:

a) All PV modules in the particular Solar PV plant being tested have been inspected in accordance with the test procedure and any PV modules determined to be defective under the test have been replaced with new PV modules.

b) Replacement PV modules have been inspected in accordance with test procedures developed by the Contractor and accepted by the principal and have been found defect free

10.6 Other Principal Requested Tests

To be advised by the principal prior to testing and commissioning stage, ideally at detailed design.

11 Completion

11.1 General

For general electrical and control system inspection and testing Section 15 of Seqwater E-SPE-STD-001 Electrical Design and Construction Standard Specification and all of B-SPE-STD-003 Commissioning Requirements Standard Specification shall be referred to and followed.

Prior to Practical Completion, ensure all individual systems have been fully commissioned and witness tested to the satisfaction of the principal.

Prior to Practical Completion, at a minimum provide the principal with the following:

h) Provide testing and commissioning certification, confirming that all conductive elements on the roof are at the same potential and connected to earth, and that no touch or step potential risks exist.

i) Submit all results with the Operational and Maintenance manuals.

11.2 As-Built Submissions

11.2.1 General

Prior to Practical Completion, submit as constructed submissions in electronic format. Include warranties, as constructed drawings, operation and maintenance manuals, as constructed shop drawings, design calculations, certificate of training, spare parts schedule, test and commissioning reports, authorities and utilities approvals, construction plan and progress photos and the like.

Data formats shall include AutoCAD (drawings), Adobe Acrobat (drawings, manuals, etc), jpeg (images), Microsoft Office suite (Word, Excel, PowerPoint) for other content.

11.2.2 Warranties

The principal shall be named as warrantee. Register with manufacturers as necessary shall be provided and copies delivered with components and equipment shall be retained and handed over to the Principal upon Project closeout.

Commencement and duration: Warranty periods shall commence at Practical Completion or at acceptance of installation, if acceptance is not concurrent with Practical Completion. Warranty periods ideally should extend beyond the expiry of DLP, but this shall be according to the final Contract stipulations between the Contractor and Principal (refer to Section 7.3 for general warranty periods).

Approval of installer: If installation is not by manufacturer, and product warranty is conditional on the manufacturer's approval of the installer, submit the manufacturer's written approval of the installing firm.

11.2.3 Software Backups

For each software-based system that the Contractor programs, an electronic copy of the complete software source code shall be provided to the principal. The as constructed software records shall include all modifications made during final testing and commissioning. As constructed software records shall be provided at Practical Completion, with another copy provided at the completion of the DLP.

11.2.4 Operations and Maintenance Manuals

Draft copy of the operation and maintenance (O&M) manuals shall be submitted capturing electrical services installation, prior to Practical Completion, for the principal's acceptance.

The aim of this is to provide a detailed understanding of the plant and its operation, an aid the training of operators, a reference for fault diagnosis and a framework for preventive and breakdown maintenance.

Authors and compilers shall use personnel experienced in the maintenance and operation of equipment and systems installed. The manuals shall have the ability for revision update to capture any key O&M issues that my occur and resolved.

Subdivision shall be done by installation or system, depending on project size.

Warning and Cautions shall be included to emphasise conditions hazardous to personnel or equipment, giving instructions to avoid the hazard. The following format to be followed:

WARNING: An examining or testing procedure or practice which must be observed or risk loss of life or injury to personnel.

CAUTION: An examining or testing procedure which must be followed or risk damage to equipment.

If referenced documents or technical sections indicate the requirement of manuals to be submitted, corresponding material in the operation and maintenance manuals are to be included.

Electronic documentation shall be in the formats of PDF, JPG and CAD.

The content of the O&M manuals shall include the following:

a) Table of contents: For each volume. Title to match cover. First volume to have an index of all volumes.

b) Version Control: Record of document revisions and versions

c) Directory: Names, addresses, and telephone and email information of Principal's consultant, subconsultants, trade, trades and names of responsible parties.

d) Installation description: General description of installation.

e) Systems descriptions: Technical description of the systems installed, written to ensure that the principal's representatives fully understand the scope and facilities provided. Identify function, normal operating characteristics, and limiting conditions. Include schematic diagrams.

f) Systems performance: Technical description of the modes of operation of the systems installed.

g) Equipment descriptions:

(i) Name, address and telephone numbers of the manufacturer and supplier of items of equipment installed, together with catalogue list numbers

(ii) Schedule (system by system) of equipment, stating locations, duties, performance figures and dates of manufacture. Provide a unique code number cross-referenced to the record and diagrammatic drawings and schedules, including spare parts schedule for each item of equipment installed.

(iii) Manufacturers' technical literature for equipment installed, assembled specifically for the project, excluding irrelevant matter. Mark each product data sheet to clearly identify specific products and component parts used in the installation, and data applicable to the installation. Do not include advertising literature.

(iv) Supplements to product data to illustrate relations of component parts. Include typed text as necessary

h) Operation procedures:

(i) Safety procedures for protection against electrical, mechanical, fire, explosive and chemical hazards including first aid and reporting

(ii) Prestart checklist, safe starting up, running-in, operating and shutting down procedures for systems installed. Include logical step-by-step sequence of instructions for each procedure

(iii) Control and switching sequences and flow diagrams for systems installed, including safety features. Also, procedures for operating and adjusting control systems

(iv) Legend for colour-coded services

(v) Schedules of fixed and variable equipment settings established during commissioning and maintenance

(vi) Testing, logging and reporting

(vii) Procedures for seasonal changeovers

(viii) Manufacturer's operational and safety literature as appropriate

(ix) Troubleshooting check lists and simple diagnostic analysis

i) Maintenance procedures:

(i) Emergency maintenance procedures, including telephone numbers for emergency services and after-hours contacts for suppliers and trades and procedures for fault finding

(ii) Manufacturer's technical literature as appropriate. Register with manufacturer as necessary. Retain copies delivered with equipment.

(iii) Detailed recommendations for preventative maintenance frequency and procedures which should be adopted by the principal to ensure the most efficient operation of the systems installed. Include an inspection, testing and maintenance programme in tabular form showing frequency, level of routine checks for each item. Include PV cleaning schedule and steps to achieve optimum output.

(iv) Safe troubleshooting, disassembly, repair and reassembly, cleaning, alignment and adjustment, and checking procedures. Provide logical step-by-step sequence of instructions for each procedure, where required including calibration and recommissioning of controls for particular devices.

(v) Schedule of spares recommended to be held on site, being those items subject to wear or deterioration and which may involve long lead times when replacements are required. Include complete nomenclature and model numbers, and local sources of supply. Include sectionalised diagrams of machines identifying component parts.

(vi) Schedule of normal consumable items, local sources of supply, and expected replacement intervals.

j) Statutory Certificates, Compliance and Quality Assurance documentation for:

(i) Electrical work

(ii) Copies of manufacturers' warranties and product warranties not supplied by manufacturer

(iii) Certificates/Contracts from network supply authority/utility

(iv) Certificate of compliance for structural integrity

(v) Product certification

(vi) Copies of test certificates for the mechanical installation and equipment used in the installation e.g., torque tests on framing, etc.

k) Drawings (which shall be submitted according to Seqwater X-PRO-STD-010 Asset Information Collection Procedure):

(i) Drawings and technical data: As necessary for the efficient operation and maintenance of the installation

(ii) Shop drawings

(iii) Site layout/string configuration, record drawings

(iv) Switchgear and control gear assembly circuit schedules including electrical service characteristics, controls and communications schematics

l) Commissioning Records:

(i) Equipment test sheets

(ii) Recorded values at commissioning

(iii) Installed system photographs or hyperlinks to the images with descriptions

m) DNSP documents:

(i) Distributed Network Supply Provider’s documentation with connection approval and updated contract

First draft of the O&M manuals shall be submitted prior to the date for Practical Completion for review and to enable the principal’s representatives to familiarise themselves with the installation. Include provisional records of drawings

a) Format: As for the final manuals, with temporary insertions for items which cannot be finalised until the installation is commissioned and tested.

b) Supply authority contract showing approval of system configuration and selection of components for no/limited/full export systems in line with reverse power protection scheme.

Final electronic copies shall be submitted within two weeks after Practical Completion. These shall incorporate feedback from review and from training of Principal's representatives, including preparation and insertion of additional data. Include a section containing commissioning test reports.

Provide operating instructions and schematic diagrams mounted alongside equipment to meet statutory requirements. Diagrams to be colour coded, colour fast, laminated and mounted.

11.2.5 Photos

Contractor shall submit all photos taken during the construction progress to the principal, as this may aid future maintenance. This may be as part of the final submission.

11.3 Training

11.3.1 Operation and Maintenance

Prior to Final Completion, explain and demonstrate to the principal's operational staff the purpose, function, operation, and maintenance of the System.

Use items and procedures listed in the final operation and maintenance manuals as the basis for detailed instruction of staff nominated by the principal.

11.3.2 Technical Assistance

Prior to Final Completion, provide technical assistance and advice to the principal's representatives regarding the operation and maintenance of the plant.

11.4 Final Certificate

The following conditions are required for the Contractor to be able to apply for the Final Certificate. The Contractor shall issue an application for Final Certificate to the Principal providing documentary evidence that the following items have been achieved:

a) The Contractor has achieved Practical Completion

b) The Works remain complete in all material respects, is able to operate safely, autonomously, and continuously at full output (subject to available irradiance and ambient air temperature) and is compliant with all requirements outlined within this Technical Specification

c) The Works have passed the Generation Guarantee Test

d) All Punch List items have been rectified to the satisfaction of the principal

e) Training has been provided as outlined in this specification

f) All defects and deficiencies in the Works have been corrected

g) Any separate defect liability periods identified under the Contract have been completed.

11.5 Maintenance

For the DLP, the Contractor shall perform all maintenance activities of the PV plant. Refer to Section 8 for additional requirements for maintenance.

11.5.1 Scheduled Maintenance

During the DLP (specified in the particular project documentation), the Contractor shall carry out routine maintenance, inspections, and tests in accordance with the equipment manufacturer's recommendations and as required to meet the Generation Guarantee Test. Where required, after the expiration of the DLP, these activities may be carried out under a separate O&M Contract/Contractor based on Principal's decision.

A brief report summarising all maintenance activities shall be developed.

At the completion of the DLP, all PV modules shall be cleaned to the satisfaction of the principal.

Any shutdown of the PV Plant required as apart of scheduled maintenance, shall be notified in writing to the principal at least one month prior to the maintenance activities.

11.5.2 Unscheduled Maintenance

During DLP, unscheduled maintenance work shall be carried out in accordance with the operation and maintenance manuals, as recommended by manufacturers of supplied equipment, and as required by referenced documents. Contractor shall provide completed checklists including test results as per IEC 62446-2. Where required, after the expiration of the DLP, these activities may be carried out under a separate O&M Contract/Contractor based on Principal's decision.

Subject to breakdown during the maintenance period, the Plant shall be repaired and maintained as required. The designated O&M Contractor shall attend emergency calls promptly as required. Any unscheduled maintenance during the DLP and maintenance period shall be attended to as per the periods defined in the O&M Contract.

11.5.3 Maintenance Program

Details of maintenance procedures and programs shall be submitted, relating to installed plant and equipment, six weeks before the date for Practical Completion.

Dates shall be indicated for service visits. Contact telephone numbers of service operators shall be stated and arrangements for emergency calls shall be described.

11.5.4 Supplies

During maintenance period, the Contractor shall provide all replacement parts free of charge.

11.5.5 Site control

Report to the Principal's designated representative upon arrival and prior to leaving the site.

11.5.6 Maintenance Record

In documentation matching the manuals, logbook pages designed for recording completion activities including operational and maintenance procedures, materials used, test results, comments for future maintenance actions and notes covering the condition of the installation shall be submitted. Completed logbook pages, recording the operational and maintenance activities performed up to the time of Final Completion shall be included.

Electronic reports are also acceptable with sign off from Contractor's project manager.

During service visits, record comments on the functioning of the systems, work carried out, items requiring corrective action, adjustments made and name of service operator. Signature of the Principal's designated representative should be obtained for these records and duplicate copies shall be submitted.

If referenced documents or technical sections require that logbooks or records be maintained, these should include this material in the maintenance records.

Where required, maintenance record activities detailed above shall be carried out beyond the DLP by the designated O&M Contractor

11.5.7 Plant Shutdown

If applicable any plant shutdowns should be coordinated with the principal and advises when plant is returned to service.

11.5.8 Continual maintenance

Prior to application for Final Certificate, a proposal for on-going maintenance of all systems and plant shall be submitted to the principal.

12 Quality Management

12.1 General

This section specifies the general quality management requirements for a PV plant. The level of detail in these requirements shall be proportionate to the size of the PV plant. Refer to project-specific scopes of work for further details.

12.2 Quality Management System

A quality management system accredited to ISO 9001 shall be followed and all Works to being performed to comply with this system.

12.3 Quality Management Plan

A Quality Management Plan (QMP) shall be submitted in accordance with the Document Schedule. The relevant QMP shall describe, as a minimum, the methodology, processes and resources the Contractor will use for quality management of the Works as well as all other aspects described herein.

12.4 Inspection and Test Plans

Inspection and Test Plans (ITPs) shall be developed and submitted to the principal cover all aspects of the Works. The ITPs shall be submitted to the principal in accordance with the Document Schedule. The Contractor shall also issue to the principal a schedule of ITPs in accordance with the Document Schedule.

All inspection and testing undertaken throughout the Works shall be in accordance with the ITPs and ensure the deliverance of the Works in full compliance with the relevant Contract. Inspection and testing of the Works shall be undertaken progressively as the Works are undertaken. ITPs shall be completed progressively as inspection and testing takes place.

Inspection and testing shall be conducted as required by the Contractor and applicable standards. Reports developed by the Contractor shall be provided to the principal at agreed intervals.

During the Principal's review of the ITPs the Principal may nominate any number of witness and/or hold points. The ITP shall be updated with the principal nominated witness and hold points and re-issue the ITP to the Principal prior to commencing the relevant aspect of the Works.

Principal shall be advised in writing of the time, date and location of each Principal nominated hold or witness point at least 2 days prior to the witness or hold point being reached. Principal shall be fully informed of any change in the timing of each hold or witness point.

The principal may elect a representative to attend any witness or hold point in their place.

The principal reserves the right to witness any or all of the Works regardless of whether the principal has nominated a hold or witness point on the ITP.

The principal may forgo any or all of the nominated hold or witness points and this shall not relieve Contractors of any responsibility.

The principal's attendance or absence at, or sign-off of, any witness or hold points shall not relieve the Contractor of any obligation.

12.5 Quality Auditing

As part of nominated QMP regular (monthly as a minimum) audit shall be undertaken of the effective application of the QMP by the Contractor and any Subcontractors including spot checks of ITPs. The results and any corrective actions and quality audits shall be recorded in a report format and issued to the principal.

The principal reserves the right to conduct audits of the application of the QMP throughout the course of the Works.

12.6 Factory Acceptance Testing

Factory Acceptance Tests (FAT) shall be undertaken by the relevant Contractor(s) and FAT documentation shall be issued to the principal for all major parts or pieces of equipment making the Plant.

The principal, or Principal's delegated representative, reserves the right to witness any FAT.

The principal shall be advised of the date, time, and location of each FAT in writing at least 2-weeks prior to the FAT being undertaken.

Relevant type test certificates for any component of Plant or equipment shall be provided to the principal within the time period allocated by the principal (according to the project documentation) and as requested by the principal.

Specific requirements for FATs are outlined in the sections below:

12.6.1 PV modules

Factory flash test results for each PV module including spares and any other result of testing performed by the OEM shall be provided to the principal.

Any other results per tests performed on PV modules by the Contractor shall be provided to the principal.

12.6.2 SAT or Fixed tilt PV module structure

Material test records shall be provided to the principal which shows that the component tolerances and corrosion protection thickness and quality is in accordance with the design requirements and applicable standards.

12.6.3 Electrical Systems

As requested, form the OEM the FAT certificates to be provided to the principal and shall include, but not necessarily limited to, the following components:

a) Transformers

b) Inverters

c) Switchgear and switchboards from the PCS and the Connection Works

d) LV distribution boards (AC and DC)

e) Auxiliary Transformers

f) Communication equipment

g) Protection and Control Systems

h) Cabling (HV, LV and fibre optic)

i) Surge arrestors.

13 Health, Safety and Environmental Requirements

13.1 General

This section specifies the Health, Safety and Environment (HSE) requirements for a PV plant. The level of detail in these requirements shall be proportionate to the size of the PV plant. Refer to project-specific scopes of work for further details.

13.2 Applicable Laws and Legislation

All Works activities shall comply with all Applicable HSE Laws, Standards, Codes of Practice and Guidelines.

In undertaking the Works, if required the principal shall nominate the Contractor to be responsible for performing any duties and/or functions of a Principal Contractor under Work Health and Safety Legislation.

13.3 Health Safety and Environment Policy

Health Safety and Environmental (HSE) policy for the Project shall be developed by the Contractor with compliance to Seqwater WHS, Environment & Heritage – Construction Management Procedure (PRO-00005) and approval of the principal and shall identify the position and commitment on HSE matters.

The HSE policy is expected to have two separate and distinct sections related to:

1) Health and Safety
2) The Environment.

The HSE policy as required shall be provided under a Project Document Schedule (indicated in Appendix A).

13.4 Health Safety and Environment Management Plans

The following plans shall be submitted to the principal for approval in accordance with a Project Document Schedule:

1) A Health and Safety Management Plan (HSMP)
2) A Construction Environmental Management Plan (CEMP), including a bushfire management plan
3) an Emergency Response Plan (ERP)

All HSE issues relevant to the Works shall be addressed in the management plans which shall also document the procedures and methods to be implemented for the term of the Contract. The principal shall review and approve the HSMP, CEMP and ERP prior to the commencement of the Works.

The HSMP and CEMP shall address as a minimum:

1) The roles, responsibilities and contact details for all parties involved in construction in relation to health safety and environmental management
2) The training, awareness and competency standards that will apply to construction staff in relation to health, safety and environmental issues
3) The health, safety and environmental laws and regulations which the project must abide by
4) Any specific development approval commitments that have been considered relating to the Works.

The CEMP shall include specific controls to be in place during the works to manage environmental issues, with a risk management table for each environmental management area (e.g., noise management or dust management) which outlines:

1) Objectives
2) Management Strategy

3) Controls
4) Performance Indicators
5) Monitoring
6) Reporting
7) Corrective Actions.

The HSMP shall include a description of the permitting system and safe work procedures for the applicable high-risk work associated with the Contract (e.g., management of hazardous substances, working at height, confined spaces, extremes of temperature and electrical switching etc.).

The HSMP, CEMP and ERM shall be reviewed at regular intervals as agreed between the principal to ensure that it remains current and relevant to the Works. The Contractor's management plans will also form the basis by which its management systems may be audited by the principal.

13.5 Roles and Responsibilities

HSE roles and responsibilities for all contracted personnel and the principal shall be clearly defined in the HSMP and CEMP. Both the HSMP and CEMP shall include:

1) A description of the HSE roles and responsibilities for key management and supervisory personnel, along with communications and reporting flows and mechanisms
2) An HSE organisation chart, which identifies the roles and responsibilities and communications flow between the contracted parties and the principal

The key HSE personnel shall have experience in the HSE area and its application in projects and site works.

13.6 Safety in Design

The Works provided and designed shall ensure operation in which safety of personnel and Works and continuity of service are the first considerations, and equally to facilitate inspection, cleaning, maintenance and repairs (this shall be considered in the Safety in Design process).

The design shall incorporate all reasonably practicable precautions and provisions for the safety of all those concerned in the operation and maintenance of the Works.

A Safety in Design process shall be undertaken in accordance with the requirements of Work, Health and Safety Legislation and shall comply with Seqwater X-PRO-STD-009 Engineering Design, Construction, Operation and Maintenance Standard Specification.

The Safety in Design process shall be conducted throughout the course of the Works and as a minimum a Safety in Design workshop shall be held at concept, preliminary and detailed design phases (refer to X-PRO-STD-009 for details of Seqwater engineering phases). Seqwater X-PRO-STD-013 Engineering Technical Hazard Study Standard Specification shall be followed for guidance on various technical hazard study techniques to be used at these engineering phases of a project to identify and manage potential risks as part of Safety in Design.

Safety in Design reports and risk register shall be issued to the principal in accordance with the Document Schedule.

Dates for Safety in Design workshops or meetings shall be specified to the principal.

The principal shall be invited to participate in all Safety in Design (SiD) workshops or meetings. All relevant parties shall also be involved in the SiD meetings and workshops and any residual risk after practical completion shall be handed over to plant O&M team (whether this is the principal or a third-party Contractor performing the plant O&M per the particular project contracting strategy).

13.7 Hazardous Materials and Solid Waste

The Contractor shall be responsible for the safe disposal of all waste, toxic and hazardous materials during the course of the Works. Such disposals shall be in accordance with the requirements of the relevant authorities and applicable laws.

The volume of waste removed from the site shall be recorded and reported and also comply with the National Greenhouse and Energy Reporting Act 2007.

13.8 Fire Protection

Adequate fire protection equipment for protection of the Works until Practical Completion including any requirements stipulated in the development approval such as the supply of fire water tanks shall be provided. The Contractor(s) shall liaise with the principal (and possibly local fire services via the principal) about fire prevention practices and their requirements, including familiarity with their capability for large-scale implementations.

Works shall be designed such that the risk to operational staff due to bush fire is considered, in particularly for implementations which span across a significant land area.

There shall be no hot work such as welding, cutting, grinding and vegetation management carried out during any fire ban periods. A 'hot work permit' system as part of its site procedures shall be implemented.

13.9 First Aid Centre

A first aid facility and trained first aid personnel shall always be available on the Site that work is being carried out, this shall be coordinated with the principal if required.

13.10 Personal Protective Equipment

Personal protective equipment should be provided by the Contractor for all Contractor's staff, employees and sub-Contractors and shall be as required by the HSMP.

13.11 Site Induction and Training

Inductions and training prior to and during any site activity and the construction works shall be a documented as a part of the HSE Management Plans. These plans shall be developed by the Contractor, for the project based on the Seqwater HSE documentation. All workers who attend site and perform Works shall complete Seqwater site inductions and the relevant required training from the list below.

Information on HSE management plans shall include required training, but not be limited to the below:

1) Confined spaces
2) Working at heights
3) Electrical safety
4) Mechanical safety
5) Traffic management
6) Hazardous substances management
7) Permit to work
8) Hot work processes
9) HSE risk assessment
10) HSE Management Systems training
11) HSE audit training
12) Emergency response plans

13) Environmental constraints and requirements

14) Any other areas required under the development approval.

The Contractor shall be responsible for providing site inductions for all personnel prior to the entering the construction Site. The site induction process shall be submitted to the principal for approval as part of the HSE Management Plans.

13.12 Audit and Continuous Improvement

As part of the HSE Management Plans, the proposed outline of an audit program must be submitted. In addition, the mechanism for continuous improvement and close out of the audit process shall be described.

13.13 Dust

For systems occupying a large land area for ground mount implementations, the Works shall be undertaken in a manner that minimises dust generation at the Site, including wind-blown and traffic-generated dust. All activities on the site shall be undertaken with the objective of preventing visible emissions of dust from the site. Should there be visible dust emissions attributable to the project occur during construction, these shall be identified and all practicable dust mitigation measures, including cessation of relevant works, as appropriate, and watering of work areas such that emissions of visible dust cease shall be implemented.

13.14 Disposal of Waste/Excess Material

It is the Contractor's responsibility to manage waste produced during the Works.

Surplus soil and excavated materials shall be disposed of at a location indicated and approved by the principal to the extent this is consistent with approvals, applicable laws, and requirements of authorities. Where required, the Contractor may be requested to dispose these materials at a location determined by the Contractor.

Other wastes including chemical waste, packaging, rubbish and vegetation shall be removed from the site and disposed in an appropriately registered facility. If immediate removal is impractical the wastes are to be temporarily stored in accordance with applicable laws, applicable standards and approvals. All approvals required for the temporary storage of waste on Site or for the disposal of waste shall be obtained by the Contractor.

Packaging materials shall be secured immediately following unpacking of contents in order to prevent being blown by the wind. Packaging materials shall be progressively removed from site during the installation process and shall not be allowed to accumulate on Site.

13.15 Requirements for Operation of Remotely Piloted Aircraft

If remotely piloted aircrafts (RPAs), including drones, are to be used for undertaking the Works, the Contractor shall provide evidence of compliance with the Civil Aviation Safety Authorities' (CASA's) rules and regulations, including evidence of valid remote pilot licence (RePL) and RPA operator's certificate (ReOC) or UAV operator's certificate (UOC) where required by the CASA.

14 Generation Guarantee Test

14.1 General

Generally, for systems that are less than 500 kW_{AC} of aggregate maximum capacity, a simpler generation guarantee test shall be performed as per Section 14.2.

For systems that are larger than 500 kW_{AC}, generation guarantee test detailed in Section 14.314.3 shall be performed.

14.2 Simple Generation Guarantee Test (for Systems ≤ 500 kW_{AC})

Energy generation and Guaranteed System Performance shall estimate for energy generated by the System and a guaranteed energy generation during the DLP.

Contractors shall offer a Guaranteed System Performance (GSP), as measured on the AC side of the inverters and adjusted for:

a) The on-site conditions (i.e., using irradiance and site temperature from either on-site sensors or the Bureau of Meteorology)

b) Failure of the Grid or other equipment not making up part of the System and not caused by the System or the Contractor

c) Export curtailment

d) Damage caused by vandalism or robbery

e) Force Majeure as defined under the Contract

The GSP shall be a minimum guaranteed kWh output for the whole of DLP. Contractors shall provide written evidence of their GSP offer.

After each year of operation, the Contractor shall provide a report detailing the generation of the System and any adjustments to the GSP value. The Contractor will be responsible for improving the performance of the System at no cost to the principal, until this measured performance is demonstrated. This shall be achieved by either rectifying defects and/or payment of Liquidated Damages. In case of defects rectification, the relevant Quality Assurance (QA) documents shall be submitted to the principal or a representative of the principal for review and approval.

If the PV Plant fails to reach the minimum generation guarantee defined by the Contractor, the Contractor shall compensate the principal for the shortfall.

14.3 Generation Guarantee Test (for > 500 kW_{AC})

14.3.1 Basis

This performance test is performed in accordance with AS/NZS 61724, Part 1 Monitoring and Part 3 Energy evaluation method, collectively referred to here as the Standard.

In this test procedure, the Measured Energy of the solar PV system is compared to the Expected Energy, i.e., the energy calculated by an agreed model using measured site environmental conditions. To pass the test, the Measured Energy shall be above the Expected Energy, with a margin applied to the Expected Energy to take account of uncertainty and risk.

The AS/NZS 61724 refers to the ‘test boundary’ which is a (generally physical) differentiation of what is part of the system being tested and what is outside of the system. The test boundary is applicable to the Predicted Energy, the Expected Energy, and the Measured Energy. The Contractor shall be responsible for, and the performance guarantee covers, everything inside the test boundary, e.g., module and inverter performance and

losses. The Contractor will not be held accountable for things outside of the test boundary, e.g., irradiance, ambient temperature, grid outages, force majeure.

14.3.2 Definitions

The following definitions apply in addition to the terms defined in the standard AS/NZS 61724.

Table 14-1 Generation Guarantee Test Definitions

Item	Definition
Standard	AS/NZS 61724, Part 1 Monitoring and Part 3 Energy evaluation method.
Test start and duration	Year 1 test: Starting from the date of Practical Completion for a period of 12 months Year 2 test: Starting 12 months after the date of Practical Completion for a period of 12 months
Test Boundary	The Test Boundary includes: the Solar PV system
Reference Data	This is the 'historical weather data'. Irradiance, decomposition, and air temperature are defined. The horizon is defined, based on assessment at a typical location within the solar PV system. As supplied by the Principal/Contractor: TMY of hourly data including global horizontal irradiance, diffuse and/or direct normal irradiance, air temperature, wind speed. Horizon profile – 0° for all directions
Predicted Energy	The predicted energy generation of the system calculated using the Reference Data and the Model as defined in this procedure. Initial predicted energy is provided by the Contractor during the tender stage. Final predicted energy will be produced from agreed Reference Data, final site design and the Agreed Model prior to Practical Completion.
Expected Energy	The expected energy generation of the system calculated using the measured site environmental conditions and the Model as defined in this procedure. Determined after the test is complete
GEPI	Guaranteed Energy Performance Index GEPI = 97%
Draft Model	Model of the Solar PV System provided by the Contractor during the tender stage.
Agreed Model	The model of the system in PVsyst with losses and configuration agreed by the Stakeholders prior to Practical Completion. Any design changes causing a change to the PVSyst model must be approved by the principal.
Measured Energy	Output of the system, including all losses and loads within the Test Boundary, unless separately excluded, i.e., the sum of the net electrical energy (active) produced by the solar PV system as measured by the generation meter(s). Auxiliary loads from equipment not supplied by the Contractor are excluded, such as StatCon. If excluded from the Measured Energy, then they are also excluded from the Expected Energy. Auxiliary loads outside the system boundary (i.e., separately metered) are not included.
EPI	Energy Performance Index EPI = Measured Energy / Expected Energy
Test pass criterion	EPI > GEPI
Undelivered Solar Energy	Equal to the greater of: 0 MWh, and (GEPI – EPI) % x Expected Energy

Item	Definition
External-cause-excluded energy	Excluded energy during times that the plant is not operating for reasons outside of the control of the Contractor. The following events reduce both the measured energy and the expected solar energy and are to be treated as curtailment because of external cause as detailed in the Standard, with expected energy reduced to the extent that the measured energy is reduced by these causes: Force Majeure Site shutdown or insufficient load to take Solar energy Grid conditions outside of the specification for the solar PV system (e.g., voltage, power factor) Curtailment due to external grid conditions (not caused by the solar PV system)

14.3.3 Test Requirements

The following requirements apply in addition to the requirements in the standard AS/NZS 61724.

Item	Description	Notes
Definition of the system	The stakeholders of the test shall agree on the definition of the system including: Aspects of system design that are being tested such as whether modules are mounted according to the design (tilt, azimuth, height, racking design) allowing the expected cooling and capture of sunlight Location and type of all measurement devices Aspects of system operation that are being tested such as whether the soiling level will be considered as part of the test.	
Grid data collection	The following parameters are to be measured and provided as part of the test: Curtailment level Voltages and power factor	Curtailment level and voltage data is collected to allow validation of data exclusions and to allow investigation of any performance issues.
Irradiance	The following parameters are to be used in the test: Global horizontal irradiance Albedo (for bifacial)	For the default test boundary in the standard, irradiance is characterised by Global Horizontal Irradiance, i.e., GHI falls outside the test boundary, but tilt gain is inside. GHI is preferable to Plane of Array Irradiance (POAI) since it is easier to measure accurately and easier to correctly input to the Model.
Temperature	The following parameters are to be used in the test: Ambient air temperature	For the default test boundary in the standard, temperature is characterised by ambient air temperature, i.e., this falls outside the test boundary, but cooling effects are inside.
Wind speed	Not needed for test - assume constant value (2m/s or use default Model wind effect coefficients).	Wind speed has a minor effect on the overall energy and can be left out of the test. Some temperature models have coefficients based on wind speed at 10m above ground whereas it is normal practice to measure wind speed at about 2m, so adjustment may be required. Also, the wind speeds may be less than in the Reference Data because of the solar PV system.

Item	Description	Notes
Rainfall / soiling	No allowance for actual soiling (assumed soiling loss used in Model)	Soiling is often a minor effect over the period of a year, so soiling is considered to be inside the test boundary to simplify the test. This means that initial cleanliness and self-cleaning of the modules is considered to be a part of the system quality, and the actual soiling level does not need to be accounted for in the Model. The Model should define assumptions about the cleaning (manual or by precipitation) of the array (as well as the cleaning of irradiance sensors). These assumptions shall be documented as part of the Model description. It is recommended that the system operator takes responsibility for the cleanliness of the array and that the losses are assumed to be independent of the weather.
Other meteorological data	The following data to be measured (may already be covered under test basis): Global horizontal irradiance Plane-of-array irradiance Albedo irradiance (for bifacial) Ambient air temperature Cell temperature Wind speed, wind direction Rainfall Soiling Atmospheric pressure Relative humidity Technical Requirements at the Solar Revenue Metering Equipment location	This data is collected to allow validation of data exclusions and to allow investigation of any performance issues.
Calibration accuracy	Use calibrated sensors for data that is input to the Model. Repeat calibration at intervals as required.	Accurate calibrations are needed for all sensors to provide a test result with low uncertainty.
Availability	To be calculated and provided as part of the test.	The Agreed Model will assume 100 % availability. Periods of unavailability are therefore excluded from the test.

14.3.4 Test Procedure

The test shall be performed in accordance with the standard AS/NZS 61724 and with consideration of the items detailed within the table of Appendix B.

14.3.5 Test Failures

After each test (i.e., the year 1 and year 2 tests), the Contractor shall provide a report detailing the generation of the System. The Contractor will be responsible for improving the performance of the System at no cost to the principal, until this measured performance is demonstrated. This shall be achieved by either rectifying defects and/or payment of Liquidated Damages. In case of defects rectification, the relevant Quality Assurance (QA) documents shall be submitted to the principal or a representative of the principal for review and approval.

If the PV Plant fails the minimum generation guarantee test, the Contractor shall compensate the principal for the shortfall based on the Contractual obligations defined and agreed upon at a Project level.

15 Spare Parts and Special Tools

15.1 General

The Contractor shall provide a list of the following spares:

a) Commissioning and start-up spares

b) Recommended spares list for two years operation

The Contractor shall provide a list of all necessary special tools, software licences, programming cables etc that are required to perform routine maintenance, operation and fault finding on the PV System and associated equipment.

Spares management should be in accordance with Section 3.7 of the Seqwater E-SPE-STD-001 Electrical Design and Construction Standard Specification.

15.2 Spare Parts Schedule

At least eight weeks before the date for Practical Completion, submit a schedule of spare parts. State against each item the recommended quantity, and the manufacturer's current price, including for:

a) Packaging and delivery to site

b) Checking receipt, marking and numbering in accordance with the spare parts schedule

c) Referencing equipment schedules in the operation and maintenance manuals

d) Packing to prevent deterioration during storage

16 Preparation for Transport

The equipment shall be shipped in the largest practical sections whilst permitting ease of handling for transportation and installation.

Preparation for shipment shall protect the component parts against corrosion, dampness, breakage or vibration injury during transportation and installation.

Each shipping container shall be identified with the contents, purchase order number and item number.

Where equipment must be split for shipping, instructions shall be provided for reassembly. Materials and special tools shall be provided for reassembly at site.

17 Changes from previous version

This Standard Specification will be regularly reviewed and updated, including the consideration of requested alterations, in accordance with Seqwater Procedure X-PRO-STD-004 Development and Review of Asset Standards.

Section Number	Change
Add additional	Add additional

18 Verification

Compliance with the document may be verified by internal audit.

19 Further Information

For further information please contact the owner of this document.

20 Appendix A – Document Schedule

Document		Description/Comment	Submission by	Initial Format	Final Format	Initial Review Period (Business Days) [HOLD]	Second and Subsequent Review Period (Business Days) [HOLD]
Tender Documents							
1	Contractor's Technical Schedules	Completed set of Technical Schedules	Tender close	PDF	PDF	NA	NA
2	Contractors Equipment Specification	Documentation and product data sheets to fully define the equipment being supplied and installed by the Contractor under the Contract. This shall include complete details and datasheets for PV modules, PV module structures and inverters. Warranty details shall be provided for all major equipment including PV modules, PV module structures and inverters.	Tender close	PDF	PDF	NA	NA
3	Contract Program	Program covering design, procurement, delivery, site mobilisation, construction, commissioning, and testing.	Tender close	PDF	Native	NA	NA
4	Site Layout	Proposed layout of the PV Plant including layout of PV Array, MET Station (if required), cable layouts, switchboard location, future battery storage area, cable corridor for future connection to the Plant Expansion and the battery storage system.	Tender close	PDF	PDF	NA	NA
5	PV Plant Architecture	Proposed electrical architecture of PV modules, strings and inverters. i.e. number of PV modules per string, number of strings per inverter/combiner box etc.	Tender close	PDF	PDF	NA	NA
6	Single line diagram	SLD of the DC and AC systems from PV modules to the connection point.	Tender close	PDF	PDF	NA	NA
7	Spare Parts List	List of components and consumables that do not satisfy the design life for the Works. The respective lifetimes, current purchase prices and stock requirements with respect to the satisfactory operation of the PV Plant for its design life shall be provided in an itemised list.	Tender close	PDF	PDF	NA	NA
8	PVSyst model	PVSyst Model for the proposed Plant showing the forecast generation.	Tender close	PDF and native	PDF and native	NA	NA
Plans and Reports							
9	Project Management Plan	As described in the Technical Specification	2 weeks after Date of Contract	PDF	PDF	10	10
10	Health, Safety and Environment Management Plan (HSEMP)	As described in the Technical Specification.	2 weeks after Date of Contract	PDF	PDF	10	10
11	Safety in Design Report	Safety in Design Report and risk register	4 weeks prior to Site Mobilisation Date. Updates to be provided throughout the design and construction phase.	PDF & Native	PDF & Native	10	10

Document		Description/Comment	Submission by	Initial Format	Final Format	Initial Review Period (Business Days) [HOLD]	Second and Subsequent Review Period (Business Days) [HOLD]
12	Monthly Report	Weekly report as described in the Technical Specification.	Each week from Site Mobilisation Date until Completion, by 6pm Friday afternoon for the current week.	PDF	PDF	5	5
13	Dilapidation Report	As descripted in the Technical Specification.	4 weeks prior to Site Mobilisation Date	PDF & Native	PDF & Native	10	10
QA Documentation							
14	ITP Schedule	Schedule of ITPs to be developed for the Works and dates to be submitted to the principal for review.	2 weeks prior to Site Mobilisation Date	PDF & Native	PDF & Native	10	10
15	ITP templates	ITP templates with location for Principal to nominate hold/witness point.	20 business days prior to the associated work commencing.	PDF & Native	PDF & Native	10	10
16	Completed ITPs	Complete signed ITPs and all supporting test documentation	Submission with relevant Payment Claim and complete consolidated set to be submitted before Practical Completion	PDF	PDF	10	10
Design Reports and Specifications							
17	Civil/Structural Design Report	Site specific engineering calculations and certification confirming that all structures making up part of the Works complies with seismic and wind conditions as described by AS/NZS 1170 and the National Building Code of Australia. Site specific evidence and calculations showing that structures have adequate corrosion protection to protect all structures for the design life.	Draft due with 30% design submission Final due with 60% design submission	PDF	PDF & Native	10	10
18	Electrical specification(s) and data sheets	Equipment specifications data sheets and cable specifications and data sheets for all DC, AC, earthing and fiber-optic cable connections in the PV Plant.	Draft due with 30% design submission Final due with 60% design submission	PDF	PDF & Native	10	10
19	Lightning Risk Assessment	Including consideration of economic loss and in accordance with AS1768:2007	Draft due with 60% design submission Final due with IFC design submission	PDF	PDF & Native	10	10
20	Earthing Study	Including PV module structures, inverters, fencing, MET Station (if required) and all other aspects of the work which require earthing.	Draft due with 60% design submission Final due with IFC design submission	PDF	PDF & Native	10	10
21	Protection study and Protection Settings Report	Protection study and Protection Settings Report	Draft due with 60% design submission Final due with IFC design submission	PDF	PDF & Native	10	10
22	Electrical losses and cable and equipment rating report and calculations and cable schedules.	Electrical losses and cable and equipment rating report and calculations. Including Cable schedules for all cables such as DC and AC cables, Comms cables etc. Cable Schedules to include for each cable type, length, route, origin, destination and unique identifying number.	Draft due with 60% design submission Final due with IFC design submission	PDF	PDF & Native	10	10

Document		Description/Comment	Submission by	Initial Format	Final Format	Initial Review Period (Business Days) [HOLD]	Second and Subsequent Review Period (Business Days) [HOLD]
23	Fault Study	Fault Study	Draft due with 60% design submission Final due with IFC design submission	PDF	PDF & Native	10	10
24	Insulation Co-ordination Study	Insulation Co-ordination Study	Draft due with 60% design submission Final due with IFC design submission	PDF	PDF & Native	10	10
Arrangement and Layout Drawings							
25	Site Layout	Final layout(s) showing the exact location of the PV module structures and footings, inverters, cable routes, fence layout, MET Station (if required) and all other aspects of the Works.	Draft due with 30% design submission Revised draft due with 60% design submission Final due with IFC design submission	PDF	PDF & Native	10	10
PV Array							
26	PV Array Earthing drawings	Including drawings showing below ground earthing layout and details and above ground earthing details for the PV arrays. Including details, specification and manufacturers datasheets for all earthing connectors and earth cables.	Draft due with 60% design submission Final due with IFC design submission	PDF	PDF & Native	10	10
27	PV structure set-out details	Set-out drawing and tables showing the set-out of PV structures across the PV Plant	Draft due with 60% design submission Final due with IFC design submission	PDF	PDF & Native	10	10
28	PV Structure detailed drawing(s)	Plans and Elevations of PV Structure Detailed dimensioned drawings of the mounting/footing/pile for the PV structures. Detailed dimensioned assembly drawing(s) of the PV structure. Detailed dimensioned drawings of the individual members clamps, brackets and components making up the structure.	Draft due with 60% design submission Final due with IFC design submission	PDF	PDF & Native	10	10
29	Lightning Protection System (if required)	Details of the lightning protection system (if required)	Due with IFC design submission	PDF	PDF & Native	10	10
30	DC cable details	DC cable layout drawing for the PV Plant Specification and manufacturers datasheets for above ground DC cable and connectors Details for DC cable installation, cable tray and/or trench details.	Draft due with 60% design submission Final due with IFC design submission	PDF	PDF & Native	10	10
31	Inverter detailed drawings	Equipment specifications and drawings for the inverters. Single Line diagram and wiring diagram of the inverters.	Draft due with 60% design submission Final due with IFC design submission	PDF	PDF & Native	10	10

Document		Description/Comment	Submission by	Initial Format	Final Format	Initial Review Period (Business Days) [HOLD]	Second and Subsequent Review Period (Business Days) [HOLD]
Connection Works							
32	Single Line Diagram (s)	Single line diagram of the PV Plant system LV/HV connection to the connection point	Draft due with 30% design submission Revised draft due with 60% design submission Final due with IFC design submission	PDF	PDF & Native	10	10
33	Protection Single Line Diagram	Protection single line diagram of the PV Plant Electrical System	Draft due with 30% design submission Revised draft due with 60% design submission Final due with IFC design submission	PDF	PDF & Native	10	10
34	Connection Works Detailed Design	Detailed design drawings including layouts, elevations, section for all Connection Works including enclosures and civil structural works.	Draft due with 60% design submission Final due with IFC design submission	PDF	PDF & Native	10	10
35	Connection Works equipment details	Connection Works equipment, termination and metering details.	Draft due with 60% design submission Final due with IFC design submission	PDF	PDF & Native	10	10
Communication and Control System							
36	Communication and control equipment details	Specifications and manufacturers datasheets for all communication network equipment	Draft due with 60% design submission Final due with IFC design submission	PDF	PDF	10	10
37	Communications cable details	Specification and manufacturers datasheet for all types of communications cable to be used as part of the Works.	Draft due with 60% design submission Final due with IFC design submission	PDF	PDF	10	10
38	Communications cable layout	Layout of communications cable.	Draft due with 60% design submission Final due with IFC design submission	PDF	PDF & Native	10	10
MET Stations (if applicable)							
39	MET Station Details	Drawing showing plan view and elevations of the MET Stations, together with instrument mounting details	Draft due with 60% design submission Final due with IFC design submission	PDF	PDF & Native	10	10
40	Power Supply Details	Details and drawings of the power supply to the MET Station	Draft due with 60% design submission Final due with IFC design submission	PDF	PDF & Native	10	10

Document		Description/Comment	Submission by	Initial Format	Final Format	Initial Review Period (Business Days) [HOLD]	Second and Subsequent Review Period (Business Days) [HOLD]
41	Instruments	Specifications and manufacturers datasheets for all MET station instrumentation and equipment, together with calibration certificates	Draft due with 60% design submission Final due with IFC design submission	PDF	PDF & Native	10	10
42	MET Station footings and post	Details of the MET station post and footing	Draft due with 60% design submission Final due with IFC design submission	PDF	PDF & Native	10	10
Completion documentation							
43	Operation and Maintenance Plans	- Operation and maintenance manuals and plan - Detailed manuals incorporating all project information and procedures necessary for the operation and maintenance of the PV Plant. -Checklist and procedures for undertaking the operation and maintenance of the PV Plant	1 month prior to Practical Completion	PDF	PDF & Native	10	10
44	Licenses and Software	Licenses and software for all systems in the PV Plant	Prior to Practical Completion	PDF	PDF & Native	10	10
45	As built drawings and reports	Drawings and Design Reports showing the as built status of the PV Plant	Prior to Practical Completion	PDF	PDF & Native	10	10
46	Practical Completion Test Results	Documented test results for commissioning tests including the Practical Completions Tests outlined in the Technical Specification including the Installed Capacity Guarantee.	Prior to Practical Completion	PDF	PDF & Native	10	10
47	Final Completion Test results	Complete detailed results, reports and test sheets showing compliance with all Final Completion Tests including the Contractors Generation Guarantee Test.	Prior to Final Completion	PDF	PDF & Native	10	10

21 Appendix B – Generation Guarantee Test Procedure

Generation Guarantee Test Procedure detail captured in the table below.

Item	Description	Further details
Data filtering	To be applied in accordance with the Standard.	Depending on the local conditions, the details of the plant design, and the addition of other data streams, the filtering criteria may be modified, but the following types of filters shall be applied and documented as part of the final report. Questionable data is examined to determine the underlying cause and whether the data should be removed. • Disagreement – value differs significantly from other sensors, e.g. due to misalignment, temporary/accidental shading, inaccurate sensors. • Range – value outside of reasonable bounds (given other conditions) • Missing – values are missing or duplicates • Dead – values stuck at a single value over time. • Abrupt change – values change unreasonably between data points. Note that the weather conditions can vary across the site and so some variation (disagreement) between sensors may be legitimate, but consistent and unexpected variation greater than the calibration accuracy would suggest an inaccurate sensor.
Night data and sunrise/sunset	Include all	Night-time losses are small, but the performance of the solar PV system could vary from the expectations and so the night-time data could be included in the guarantee. Likewise, the start-up and shutdown of the inverters can vary from expectations. If night-time data is excluded, then the threshold needs to be clearly defined so that it includes inverter start-up performance and can be applied in the same way to the measured energy data, the weather data, and the Model (which may be limited to hourly averaged data). The specifics of handling data near sunrise and sunset should be defined both with regard to whether they are included in the model and with regard to whether the measured irradiance data are confirmed to be shade free near sunrise and sunset. Various other parameters need to be set taking into account the inclusion or exclusion of night-time data, e.g. availability.
Time interval	Weather data collected at same interval as meter data. Weather data loaded into Model with averaging applied as required.	Ensure that the time interval of the measured variable input data is consistent with the input requirements of the performance model.
Time stamp alignment	Data timestamped with local standard time (no daylight time) Start/end of period to be stated	Documentation of time stamps should follow ISO 8601:2004. Make sure that hourly data, such as hour ending, hour beginning, or middle-of-hour average, are at the proper time stamp. Also confirm alignment between the collected data and the software conventions for time stamp format (preferably following ISO 8601), treatment of “summer” or “daylight savings” time, inclusion of leap days, and indication of midnight as 0:00 or 24:00, if applicable.
Averaging multiple sensors	Average readings from multiple sensors (irradiance, temperature, etc.). A minimum number of valid sensors can be defined.	If the data inspection identifies error in the output of a sensor, that data should be discarded before taking the average of the data pool. This action should be done only with mutual consent of the stakeholders.

Item	Description	Further details
Substitution of back-up data for erroneous or missing data	In the case where irradiance, wind, temperature and/or production data are missing from the sensors but are available from another source that is representative of the actual data, the data from the other source may be substituted.	
Calculate expected energy	Meteorological data shall be input into the Model and Expected Energy calculated for inclusion in the test: • During times of unavailability as explained in the Standard • During times of full availability as explained in the Standard • Total expected energy	
Analyse discrepancies	If the expected energy deviates from the predicted energy significantly, then a root cause diagnosis should be completed.	For example, such a diagnosis might be that the weather for the year was unexpected, the simulation model is different than the as-built plant, or there was unusual missing data. The test report should comment on whether the test should still be considered valid.
Calculate measured energy	Measured energy shall be included in the test: • During times of unavailability • During times of full availability • Active power	The measured energy is the result of all energy generated by the PV Plant as measured at the Solar Revenue Metering Equipment during the test period after subtracting out energy associated with parasitic power losses. If substitutions were made for missing data, care should be taken that the measured energy production is estimated in a way that is consistent with how the expected energy for that time period was defined.