Solar Power Supply Systems

ESS-09-01

Applicability

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SMS

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1.1	18 Sep 23		Reviewed solar battery capacity requirements and maintenance response time with the business unit signal engineers. Document updated including the suggestions provided and other minor updates.
1.2	10 Nov 24		Updated based on feedback from Inland Rail Solar Supply implementations and other minor updates

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1 Introduction

1.1 Purpose

This standard defines the performance requirements for solar power supply systems – following a system engineering approach for the entire lifecycle of the solar power supply system. It is intended that this document is used in conjunction with Australian standards and industry best practices.

1.2 Scope

Scope of this document covers the requirements of solar power supply system for the railway signalling application on the ARTC network which is intended to power:

- 110/120-volt AC
- 240-volt AC and
- DC low voltage.

This is applicable to all personnel who may have a requirement to be involved in any stage of the life cycle of a solar power supply system.

This standard is applicable to the entire ARTC network.

1.3 Standard Owner

The Manager Engineering Services is the Document Owner. For any query, initial contact to be made at standards@artc.com.au

1.4 Responsibilities

The Signal Design Engineers, Project Signal Engineers, Project Manager, Signal Maintenance Engineer and Business Unit Managers are accountable for implementation of this standard. This is necessary to ensure consistency, maintainability, and reliability of the Signalling System.

The supplier is responsible for compliance and confirmation to this standard and applicable Australian and International standard.

1.5 Reference Documents

Document Code	Title
ISO/IEC/IEEE 15288	Systems and software engineering — System life cycle processes
AS/NZS 1768	Lightning Protection
AS/NZS 3000	Electrical Installation
AS 5139	Electrical installations - Safety of battery systems for use with power conversion equipment
AS/NZS 4509 series	Stand-alone Power Systems
AS3011 series	Electrical Installation – Secondary batteries
AS/NZS 5033	Installation and safety requirements for photovoltaic (PV) arrays
AS/NZS 1170.2	Structural Design Action - Wind Loads
AS 7703	Railway Signalling – Power Supply Systems
IEC61730 Class A	Photovoltaic (PV) module safety qualification

IEC 61646	Thin-film terrestrial photovoltaic (PV)modules – Design qualification and type approval
IEC61215	Terrestrial photovoltaic (PV) modules – Design qualification and type approval
IEC 61727	Photovoltaic (PV) systems – Characteristics of the utility interface
ESC-07-01	Installation of Trackside Equipment
ESC-07-03	Small building, Location case, terminal cases, and general-purpose case
ESC-11-01	Construction of Cable Route and associated civil works
ESA-11-01	Cables for Railway Signalling Applications - General Requirements
ESS-09-02	Signalling Power Systems
ESI-11-10	Earth Leakage Detector Testing
ESC-09-02	Lightning and Surge Protection Requirements
ESC-21-01	Inspection and Testing of Signalling - Roles, Responsibilities and Authorities
ESC-21-02	Inspection and Testing of Signalling - Plans, Programs, Documentation and Packages
ESC-21-03	Inspection and Testing of Signalling - Inspection and Testing Principles
ESC-21-04	Inspection and Testing of Signalling - Standard Forms
EGP-04-01	Engineering Drawings and Documentation

1.6 Definitions and Abbreviations

The following terms and acronyms are used within this document:

Term or acronym	Description
AC	Alternating current
AGM	Absorptive glass mat
COTS	Commercial off the shelf
Depth of Discharge (DOD)	The amount of charge removed from a fully charged battery to completely discharged. Expressed as a percentage of battery's rated capacity.
DC	Direct current
FAT	Factory Acceptance Testing
Hz	Hertz
IBC	Interdigitated Back Contact
Irradiance	Radiant solar power incident upon unit area of surface, measured in watts per square metre.
Maximum Depth of Discharge	The amount of discharge the batteries can experience before suffering damage or reduced life.
MPPT	Maximum Power Point Tracking

PV	Photovoltaic
RAMS	Reliability Availability Maintainability and Safety
SAT	Site Acceptance Testing
STC	Standard Test Conditions
UPS	Uninterruptable Power Supply

2 General

2.1 Fundamental Principles

Electrical systems are inherently hazardous to people and other equipment. AS/NZS 3000 provides requirements and recommendations that are designed to reduce risks with regards to electrical installations. This standard compliment those requirements and recommendations by addressing the specific requirements around solar power supply systems.

The primary characteristics of a solar power supply compared to conventional 'mains' power supplies are:

- Solar systems generate and store DC energy. Reticulated energy from a local mains supply is AC.
- Solar systems are coupled with battery storage systems, to provide power for an installation for times when sunlight is unavailable – including for as many 'no-sun' days considered in the design.
- Solar system sizing and battery storage system sizing is highly sensitive to the design assumptions and considerations. Some of which include but are not limited to:
    - the size of the loads to be supplied,
    - the operating duration of the loads,
    - the operating voltages of the loads,
    - AC or DC,
    - the static and transient loading of the loads,
    - the maximum duration for continuity of supply (or 'autonomy'),
    - seasonal and locational changes in irradiance levels at the site, etc.
- Solar systems are designed to cater for both the static loading and the transient loading. As such, the system components (e.g., inverters) need to be carefully selected to achieve this.
- Solar power produced is proportional to the level of solar irradiance which is directly exposed to the PV module – hence, it is affected by the PV module's tilt angle and orientation, time of day, cloud cover and shading.
- Solar systems are susceptible to output power reduction which is disproportionate to the amount of area that is directly shaded on the PV modules by any nearby obstacles.
- Solar systems are also susceptible to power reduction due to dirt and dust or other fouling of the PV module surfaces, as well as changes in the PV module operating temperature.

- Solar systems are nameplate rated at 'standard test conditions' (or STC) and actual performance may be different from name-plate ratings due to e.g. temperatures, impinging irradiance levels, etc.
- Battery systems have an effective maximum discharge level which should not be exceeded to prolong the life of the batteries.
- Batteries are susceptible to damage caused by heat and are subject to a maximum rate of charge to prevent overheating and are managed by charge controllers.
- Batteries are rated such that they supply a large current for a shorter amount of time, or a small current for a longer period.

2.2 Determining the need

ARTC's preference is to use an AC reticulated supply from an electricity authority for powering signalling applications. A solar power supply system shall be used only when the provisioning of electricity authority power supply is either not possible or is not deemed to be cost effective due to the installation costs of a reticulated system. Decisions made shall be recorded by the project and agreed by the business unit signal engineer/signal manager or equivalent. Decision process shall consider the life cycle cost including initial installation cost, replacement cost of solar equipment, inventory management cost, training, and additional maintenance resource required.

Where there is a requirement for a new signalling power supply, consideration shall be given to the following items to determine the most appropriate power supply system.

- Location
  - is there cost-effective access to a local 'mains' reticulated AC supply? – considering the proposed installation's entire life cycle, including possible increases of usage of equipment powered from that supply?
  - is there adequate and safe access for maintenance personnel?
  - are there adequate spare parts available and what is the maintenance response time during failures?
  - is there a risk of vandalism, and can that risk be addressed?
  - is there network coverage for voice and/or data communication?
- Load
  - is the maximum load known?
  - what is the proposed equipment to be operated?
  - is the equipment carrying out a safety critical function?
  - how many different operating voltages are in the location? - is it possible for a single solar power supply system to deliver the overall and total system power requirements?
- Autonomy
  - is the equipment required to operate autonomously during power outages?
  - what level of autonomy is required?

Once a high-level base system requirement has been determined, then the most appropriate signalling power supply system can be provisionally chosen.

Where the determination is that a solar power supply system is the most suitable, it shall be risk assessed to determine the exact arrangement that matches the requirements of the system that the solar power supply system is supplying.

3 Design

The signal design team shall establish and document typical power loads for the proposed equipment. The process for determining the nominal static and transient power loads for the entire installation shall be undertaken.

Once the detailed design loads have been determined, the chosen power supply arrangement shall be revisited to confirm that the chosen solution is still valid. Where total loading exceeds the proposed arrangement, a local mains supply may become a more cost effective and reliable solution.

The requirements below should be used to determine the solar arrangement, equipment sizing and system criteria in conjunction with Australian standards and industry best practice.

3.1 General Design requirement

The following requirements shall be considered as part of the general design requirements.

- All equipment used in a solar power system design shall be Type Approved.
- Components used in a solar power system shall be designed, as a minimum, to have N+1 redundancy.
- Batteries are to be specifically designed for use with solar power supply systems.
- The design shall detail the brand, number of solar PV panels and the technical details of each panel.
- The design should note the maximum tolerable input power allowable to protect from damage in the event some panels are changed with higher output panels.
- The design may include battery arrangements such that individual batteries can be disconnected without affecting the system’s overall operation and autonomy.
- Each solar PV panel shall comply with IEC61730 Class A and either IEC61215 or IEC61646 standards.
- The design should consider smart isolation of failed solar PV panels to avoid entire arrays failing.
- The use of solar PV panels capable of detecting failure is desirable.
- Inverters and solar controllers shall detect output failure.
- An oversupply co-efficient figure of 1.3 is to be used in all calculations for component sizing and selection as specified in AS4509.
- The design shall include a soiling or derating factor of 90% for high dust or similar areas and 95% for all other areas. These values are to be used for all calculations for component sizing and selection as specified in AS4509.

- All settings and details for solar controllers to be included in the circuit book in a tabular form.
- Battery details to be included in the circuit book in a tabular form.
- Temperature derating shall be considered in accordance with AS4509.
- Circuit breakers shall be used.
- The design should consider whether a fixed permanent motor generator set is required as back up in specific locations where a failure of the solar power system may generate unacceptable operational outcomes and/or where response times by maintenance personnel is excessive. The final proposal shall be agreed in consultation with regional ARTC signal maintenance engineer.
- Switchboards and isolation or protection devices can utilise commercially available equipment and shall meet relevant Australian standards.
- Equipment shall be arranged such that there is ease of access for maintenance to manage associated risks.
- Consideration shall be given to the requirements for spare parts / modules and training.
- Consideration shall be given to the usage of main storage batteries with a voltage of 48VDC to align with industry best practices for telecommunications deployments.
- Solar system design should include the below:
    - At least 2 ‘strings’ of solar PV modules – with accompanying charge controllers
    - Multiple redundant batteries arranged such that batteries can be removed and/or replaced without affecting overall system output.
    - DC-DC converters used for each low voltage signalling supply should be N+2.
    - DC-AC inverters (where used) should be N+2.
    - A logging and monitoring system within the solar power supply system that shall be capable of being configured to raise warnings and alarms as per section 3.12
- RAMS shall be considered in the selection and development of the solar system, using sufficient assessment and assurance
- The solar system shall achieve the RAMS requirements as set out by the project team
- In some applications where impact to safety and operations, identified in the safety in design risk assessment, is acceptable to the business units, above requirements may be relaxed. Wind generator technology may be considered to supplement solar power supply sites where suitable conditions and evidence exist. Where such an opportunity is presented, the designer shall make representation to ARTC.

3.2 System Capacity

Australian standard AS 4509 - Stand-alone power systems, shall be utilised for the basis of all system charging and capacity requirement calculations, including the limitation imposed by worst case sunlight hours for given area.

A 10% additional allowance shall be used for both charging and capacity calculations.

Note: When completing the calculations using AS 4509 - Stand-alone power systems, there are further inputs required for each table. These inputs are derived directly from the manufacturer's specifications for the specific equipment selected.

A solar power supply system shall also comply with AS/NZS 5033 and Clean Energy Council (CEC) design guidelines.

3.2.1 Battery Capacity

The design calculation of battery capacity shall provide the required autonomy which is the number of days of operation of the system without energy input from solar arrays under normal operating conditions before exceeding the maximum depth of discharge.

The following information outlines the generic requirements of battery capacity for various solar system.

System 1 – A DC to DC system with a nominal battery voltage of 12,24, 48 or other suitable voltage. This arrangement has no alternate power source and has a reliable maintenance response time to site of less than 3 hours to address system repairs.

- Battery capacity – minimum 3 days

System 2– A DC to DC system with a nominal battery voltage of 12, 24, 48 or other suitable voltage. This arrangement has no alternate power source and has a maintenance response time to site of greater than 3 hours to address system repairs.

- Battery capacity – minimum 7 days

System 3 – A DC to DC system with a nominal battery voltage of 12, 24, 48 or other suitable voltage. This arrangement has no alternate power source and assumes large specialist battery possibly difficult to change under call out conditions with long lead times to replace.

- Battery capacity – minimum 10 days

System 4 – A DC to 120 or 240-volt AC system. The site has a reliable maintenance response time to site of less than 3 hours to address system repairs. The AC load side has a backup motor generator with a UPS. The motor generator shall start after either 3 days, or inverter output failure.

- Battery capacity – minimum 3 days

System 5 – A DC to 120 or 240-volt AC system. The site has a reliable maintenance response time to site of greater than 3 hours to address system repairs. The AC load side has a backup motor generator with a UPS. The motor generator shall start after either 7 days, or inverter output failure.

- Battery capacity – minimum 7 days

Design engineer shall consult with the business unit signal engineer or signalling manager for additional local requirements, for example provision of higher battery capacity based on the additional maintenance response time required or for any other site-specific requirements. Design decisions shall be agreed with the business units and documented in the design report.

3.3 Solar Panels

The following criteria shall be used in determining the ideal panel type for each specific implementation and location.

Efficiency

Panels' cell type, size, design, and configuration vary and affect the total panel efficiency. Preference for selection of panels shall be given to the highest efficiency panels.

Size

Panel size is not usually related to output or efficiency. Size consideration is factor of the space and location to be installed – and may be the determining factor in panel selection.

Other

Other factors to consider when selecting panels are factors such as a high retained power over a long period of time, bifacial modules or warranties. Preference for the selection of panels shall be given to panels with 80% or higher retained power after 25 years of use.

3.4 Design requirement for Solar Panel mounting frames

The design shall specify the inclination or pitch of the solar PV panels for optimum performance based on the location's latitude and the worst solar radiation period (usually winter). The worst solar radiation period is derived from a solar study of that site, or, a similar site at the same latitude and orientation. The solar PV panels shall be orientated to face within 10 degrees of true north unless site requirements dictate otherwise.

Solar PV panel support frames shall allow for simple quick replacement of solar panels. Mounting shall utilise a tamper proof fixing and where this requires a specialised tool, they shall be made available for maintainers.

Support frames should allow for easy expansion of frames if extra solar panels are required.

The support frame material is to be structurally sound and shall be suitably wind rated to cater for worst case winds for the area. AS 1170.2 details requirements for calculating wind loads.

The mounting structure is to be all weather and long lasting, with a minimum service life of 25 years.

3.5 Requirements for Solar Controllers

They shall:

- have an efficiency of >90%.
- use MPPT technology.
- be microprocessor controlled.
- have an external connection for PC interface and remote logging.
- incorporate automatic temperature compensation.
- be protected against solar array short circuit.

3.6 Requirements for DC to AC Inverters (where used)

They shall:

- have an efficiency of >90%.
- be microprocessor controlled.
- have an external connection for the PC interface and remote logging.
- be a pure sinewave.
- be in the range of 48Hz to 52Hz.
- incorporate automatic temperature compensation.
- be protected against:
    - Inverter over temperature
    - Inverter over current
    - Inverter output short circuit
    - Inverter input reverse polarity

3.7 Requirements for DC to DC Converters (where used)

They shall:

- have an efficiency of >90%.
- be microprocessor controlled.
- be an external connection for PC interface or remote logging.
- incorporate automatic temperature compensation.

3.8 Storage Batteries

- The maximum depth of discharge (DOD) shall be the manufacturer specification minus 10%.
- The nominal battery discharge rate shall be C100.
- The AS4509 calculation tables require the battery supplier and type as an input.
- The battery arrangement shall have minimum 10-year rated life.
- There shall be a preference for lithium batteries due to their greater operational efficiency.
- The temperature charging range shall be from minus 5 (-5) to plus 50 (+50) degrees C.
- The temperature discharging range shall be from minus 10 (-10) to plus 60 (+60) degrees C.
- The battery operating temperature range shall be from 0 to plus 70 (+70) degrees C.
- Batteries with different characteristics shall not be connected to each other within the same battery bank.
- Battery details to be tabled and included in the circuit book.

3.9 Cables and Cable Routes design

The designer shall calculate the required cable size as per required application in accordance with ARTC signal standards.

All cable routes shall be designed as per ARTC standard ESC-11-01.

3.10 Equipment Enclosure

Enclosures are to be designed and installed as per the ARTC standard ESC-07-03 – Small building, Location case, terminal cases, and general-purpose case. The entire system should be modular and be able to be easily transported as one unit. The enclosure selected shall consider the footprint required so as not to restrict vehicle access.

The equipment enclosure shall be able to be connected electrically to an adjacent enclosure or separate battery enclosure by underground conduit.

The design shall include an external weatherproof wall mounted 240VAC 10amp AC male socket to allow the connection of a portable motor generator of less than 2KVA to charge the battery system should there be a failure of the solar charging system. The male socket shall be isolated from all site power sources by a double pole isolation switch located within the location or building.

There may be a site requirement for a break before make changeover switch to be installed such that the switch will isolate the solar power supply system from the busbar before allowing the generator sourced supply to connect to the load via a suitable charger.

The enclosure shall be designed such that maintenance actions on batteries can be safely accomplished using sliding battery trays is considered when selecting racks – this shall include the method of securing batteries. In this instance the racking shall be designed to accommodate a 20% additional load over the battery weight.

Battery enclosures with either vented and/or valve regulated (sealed) batteries shall manage ventilation in accordance with AS5139. Note that gel and AGM batteries under conditions of overcharge, can emit significant amounts of hydrogen gas external to the battery, constituting a hazard.

3.11 Earthing

As a general earthing and surge protection reference, ESC-09-02 shall be used.

The resistance of the earthing system to the general mass of earth at each location shall be measured and recorded at regular intervals. The maximum earth resistance shall be 5Ω in dry ground.

The earthing system consists of a main earth bar located within the equipment housing connected to single main earth wire joined to a single main earth electrode. In some installations the main earth electrode may be shared with an earth mat to provide the required low earth resistance value.

The total resistance of both the main earth wire and its connection to the earth electrode and/or mat shall not exceed 0.5Ω. The main earth wire and its connection to the earth electrode and/or mat shall be mechanically secure and protected, and corrosion protected. The earth electrode and/or mat connections shall be visible and accessible.

All exposed metalwork of the installation shall be securely equipotential bonded to the main earth bar including each separate equipment rack.

Where fitted, ELDs shall have a manual test facility to ensure that they operate correctly at the specified leakage current. ELDs should have either an internal logging facility, or a communications port connection for remote access for data downloads.

3.12 Solar System Monitoring Requirement

Where devices have been specified to be monitored, their alarm and warning outputs are to be wired to a common set of terminals to allow easy connection to an independent telemetry or monitoring system. Monitoring equipment should be able to connect to local and remote systems and be able to provide required indications and alarms as required. Following alarms are to be provided as a minimum depending on the site-specific design.

1. Battery Warning – low battery output warning
2. Battery Alarm – maximum depth of discharge battery alarm
3. Battery failure or disconnection – Battery failure alarm
4. Charging system output failure – Charger failure alarm
5. Solar theft – Charger failure alarm
6. AC Alarm – no inverter output alarm
7. DC Alarm – DC-DC converter output alarm
8. Temperature alarm

4 Constructability Requirements

Considering constructability requirements will identify obstacles before a project is built to reduce or prevent error, delays, and cost overruns. The term “constructability” is referred to as:

- the extent to which the design of the entire system facilitates ease of construction, subject to the overall requirements for the completed system,
- a system for achieving optimum integration of construction knowledge and experience in planning, engineering, procurement, and field operations into the building process whilst balancing the various project and environmental constraints to achieve overall objectives, and,
- a system for achieving optimum integration of construction knowledge in the building process and balancing the various project and environmental constraints to maximise achievement of project goals and building performance.

These constructability considerations shall be incorporated into the design process.

Installation of the solar system shall be as per site specific requirements and in accordance with applicable ARTC and Australian standards.

It is preferred to use installers who are accredited by the Clean Energy Council.

4.1 Site Access and Egress

The selected site for the installation of the solar power supply system shall allow all construction activities to be undertaken by suitable personnel using standard vehicles.

The arrangement of the site shall consider existing physical conditions such as culverts, drains, neighbouring properties, trees, or other conditions that may have a material negative impact upon the overall installation.

4.2 Security Fencing

Where there may be risks associated with theft and/or vandalism, fencing may be required, unless the risk is assessed in conjunction with the local signal engineer and/or maintenance management. If it is found to have a reliability impact in the future, this decision may need to be reconsidered.

For example, remote or low-density areas may be considered low risk for vandalism and theft.

4.3 Solar Panels and Mounting Frames

Solar panels need to easily assessable for cleaning and replacement. Where the mounting arrangement is pole mounted, there shall be ladder brackets affixed to the mounting structure to allow the safe placement of an appropriate ladder for this purpose or fold down mast may be used.

All wiring shall be secured underneath panels for mechanical and UV protection and shall be routed internally within one of the mounting posts for security. The post shall have an inspection opening within 500mm of ground level for inspection purposes. There shall be an underground conduit installed connecting the base of the mounting post to the enclosure where the batteries and solar controller are located. Installation shall consider the roof litter, bird dropping and vegetal material for cleaning of the panels.

Use of existing buildings should not be preferred for solar panel mounting. New structures, buildings or pole mounting arrangements shall be preferred.

Site specific structural design certification will be required which includes:

- confirmation of the structural suitability of the existing buildings for the proposed PV system framing and panels including additional dead and wind loads.
- any alteration and additional strengthening works required on existing roof structure.
- maximum short-term dead loads during construction and recommended locations. The dead load shall include total load from any unit of plant or equipment.
- confirmation of the suitability of the recommended fixing systems of the solar PV
- framing, if not in compliance with the framing manufacturer instructions including maximum roof height and purlin spacing.

4.3.1 Placement

The placement of the solar panels can directly affect their performance. The following requirements shall be considered in relation to the placement of the panels. They shall:

- Face north for maximum charge.
- Be positioned to avoid shading from neighbouring structures and other objects both within and outside the railway corridor.
- Face away from the rail to avoid drivers' interference.

- Not interfere with the normal functioning of other rail assets and not interfere with road and signal sighting.
- Where not all requirements can be met, the final placement shall be agreed with the business units and documented in the design report.

4.4 Enclosures

All enclosures shall be installed in accordance with ESC-07-01, with appropriate consideration in respect of flooding, access, and protection by bollards.

Consideration may be given to the installation of a shade structure over the enclosure/s to manage the effects of solar radiation and temperature rise within the enclosure. Consultation shall take place with the local signal maintenance engineer to confirm this requirement.

4.5 Footprint and Expandability

The selected site for the installation of the solar power supply system shall have a footprint, spacing and civil works that include room to expand and install more solar equipment for future proofing.

5 Testing and Commissioning

This section covers the requirement for installation, testing and delivery of solar power supply systems on the ARTC Network.

A Test Certificate to be provided on completion of the testing of the solar power supply system on site – this could be the manufacturer SAT certificate and testing results or a separate solar panel testing sheet for each panel or string of panels.

Warranty certificates for equipment supplied as part of a solar power supply system including ancillary equipment shall be included in the handover package.

Following the installation of new solar power supply systems, they should be inspected for the following issues:

- Installed in accordance with the signal design requirements where signal designers have produced the overall solar power supply design, and,
- Installed in accordance with the solar power supply system’s manufacturer’s requirements.
- Where there is a conflict between the designs this should be raised to the project signalling team and resolved.
- Installed in accordance with the applicable standards, procedures, and good practice.
- Installed in a manner that will not adversely impact upon other signalling equipment.
- Installed equipment is identified as to its design identification.
- All power terminals are clearly labelled with the applicable voltage and polarity.
- Danger and/or warning labels are applied as appropriate.

For more information on the testing and commissioning process, please refer to the standards from ESC-21-01 to ESC-20-04.

5.1 Preparation for Commissioning

Prior to commissioning into service, the solar power supply system should:

- have all preliminary inspections and tests completed and documented – SAT is an example of this.
- have the output side of all equipment isolated.
- be checked to ensure that the input voltages are set and are within the design range.
- be powered up and given a final check of output voltages.
- then have the output busbars connected to the live output.

5.2 Solar Controller / Inverter / Charger

This section is applicable to all configurations of equipment that are used in the management of battery charging and regulating output.

- Solar controller
- DC-AC Inverter
- DC-DC Converter

The solar controller arrangement shall be installed and configured as per the manufacturer’s specification and requirements.

A FAT and SAT certificate shall be completed and returned to ARTC that shall include the following data.

- Solar array output voltage/s – there may be more than a single array string per system.
- Maximum solar array output current – per array string.
- Output voltage – to the main battery storage system.

5.3 Batteries

A SAT certificate shall be completed and returned to ARTC that shall include the following data.

- Voltage of Individual battery packs – each battery pack voltage to be individually listed.
- Voltage of entire battery bank – at the outgoing terminals or solar power supply system outgoing main circuit breaker
- Capacity of the entire battery bank – amp/hrs
- Maximum charge current of the battery system
- Maximum discharge current of the battery system – as per the manufacturer’s data sheet

5.4 Equipment not in service

All solar power supply equipment that is installed and not in service should be tagged with a label that it is not in service. The input fuses for the equipment should be removed and any circuit breakers switched off and tagged.

5.5 As-built drawings and documentation

At the completion of the construction and commissioning activities, the design drawings and documentation shall be updated to an “as-built status”. Copies of the drawings and documentation with marked up changes shall be available to maintenance staff immediately after the system is brought into service, with certified copies of drawings returned to the signal designer as per existing procedures.

The following items are expected to be delivered as a minimum at the time of handover to ARTC.

- List of equipment specified including technical specification and user manuals for all supplied panels, inverters, and all system components.
- Completion of the solar panel module and inverter(s) checklist
- SAT Certificate.
- Array frame engineering certificates for wind and mechanical loading.
- A generic structural engineering certificate based on industry best practice for the equipment not covered by the frame engineering certificate.
- Certificate of Design Compliance in accordance with related ARTC and Australian standards.

5.6 Bringing into Service

At the time of bringing into service a new or altered solar power supply system, the commissioning engineer or their delegate shall ensure that all documentation has been completed and is made available at the solar power supply location. This documentation shall be compiled within a folder that is able to be stored safely away from equipment within the location. The folder shall contain as a minimum.

- Instruction manuals.
- A list of actions to be taken in the event of an earth fault alarm within the solar power supply system, where earth fault monitors are fitted to the solar power supply system.
- And other information that may be deemed useful for front line maintenance and fault-finding personnel.

6 Operation and Maintenance

Preventative maintenance shall be carried out in accordance with existing service schedules for the individual equipment items that form a solar power supply system.

Where no service schedule is available, advice and information should be sought from the equipment manufacturer. This information shall be assessed so that a new service schedule and maintenance interval can be formulated, approved and uploaded into Ellipse.

6.1 Solar PV Arrays

Solar PV arrays shall be regularly inspected to ensure that the solar PV array is in good condition and the sun-facing surface is clean and undamaged. Mounting hardware shall be checked for mechanical security.

To provide on-site reference information, there shall be a solar PV array maintenance card that shall indicate the following values for both individual solar panels and the entire solar array, as specified by the manufacturer of the solar modules:

- Rated Power (Pmax)
- Voltage at Pmax
- Current at Pmax
- Short circuit current
- Open Circuit Voltage

Note: The manufacturer's electrical data shall be specified under Standard Test Conditions (STC) which are:

- Irradiance = 1,000 Watts/m2
- Cell Temperature = 25°C
- Air Mass = 1.5 spectral irradiance distribution

6.2 Batteries

The following information should be recorded for the battery system:

- battery system charging voltage - maximum.
- battery charging current - maximum.
- Nominal battery voltage with solar controller disconnected.
- Measured battery discharge current with solar controller disconnected – this will be site specific.
- time and date.

6.3 Earthing

Earth connections shall be inspected to ensure that connections are secure.

The total resistance of both the main earth wire and its connection to the earth electrode / mat shall be measured and recorded periodically. The main earth wire and its connection to the earth electrode and/or mat shall be inspected to ensure that they are mechanically secure, and corrosion protected.

Locations shall be inspected to ensure that all equipotential bonding is mechanically secure.

Where fitted, ELDs shall be tested to ensure that they operate correctly at the specified leakage current.

6.4 Surge Protection Devices

Surge arrestors shall be selected such that their rating is sufficient to handle the maximum expected current from the solar PV panels to the chargers continually.

Surge arrestors shall be inspected to ensure that they are in good condition with health status indicators if fitted showing they are good / normal. Arrestors that do not have an indication shall be inspected to ensure that there is no visual evidence of damage from power surges.

6.5 Remote Monitoring Systems

Testing of the functionality of all remote monitoring system inputs shall be carried out. These tests are to ensure that the activation or status change of each system warning or alarm is correctly transmitted to the nominated monitoring point.

7 Modifications and Alterations

Modifications and alterations shall only occur when a signal design has been authorised for a particular site.

Where 'Like for Like' replacements are required, these shall be carried out under existing standards and procedures.

In an emergency scenario the Signal Maintenance Engineer, or their delegate, may authorise works to be carried out to repair or replace equipment within a solar power supply system to ensure the ongoing security of that supply. Written details shall be made of the proposed changes so that an assessment can be made of the longer-term impact of the changes, and, whether any further remedial actions may be necessary to restore the site to the original configuration.

7.1 Changes in Signalling Equipment

The nature of the design of a solar power system is such that all equipment within the supply area is assessed and included in the maximum demand calculations for that system. Where modifications are to take place that either add equipment or change the type of equipment already installed, the signal design team shall review the current power calculations to ensure that the proposed changes do not have a negative effect upon the existing solar power supply system such that there is a loss of capacity that may impact upon the reliability of the system with respect to the requirements of this standard.

8 Decommissioning and/or Disposal

Where a solar power supply system is to be decommissioned and/or removed and disposed of, the following steps shall be taken.

Decommissioning or system power down shall only occur when a signal design has been authorised for a particular site. This may be due to a power system upgrade to a main supply, or, where a site is no longer required and is to be completely removed – such as a mid-section level crossing that is closed.

Disposal of equipment shall be in accordance with the requirements of each state or territory where the installation is located. Disposal shall consider the following.

- hazardous substances such as battery acid or gel
- electronic components
- recyclables
- reusable equipment
- heritage items
- culturally significant items
- items suitable for disposal at landfill – concrete foundations etc