1. Introduction

This technical note is issued by the Asset Standards Authority (ASA) to set out the essential technical requirements for installation of inverter connected photovoltaic embedded generator systems on TfNSW facilities.

Embedded generation systems, of which photovoltaic (PV) systems are one category, when connected to the RailCorp network can affect the operating conditions, voltage profile and loading on the feeder and distributor.

The requirements of this technical note shall be incorporated into future ASA LV electrical standards.

Application for connection documentation, in accordance with T HR EL 17001 ST Electrical Distribution System Installation Connection and Inspection, should be submitted by the AEO designer as early as practicable in the design phase.

In addition, until the processes have matured, it is recommended that Asset Standards Authority, Electrical unit is invited to comment, in the design phase, on the project scope of works and AEO assurance interfaces.

2. Purpose

The purpose of this document is to outline the requirements, to proponents of embedded PV generation systems, for the connection of PV systems to the RailCorp distribution network.

These guidelines should be read in conjunction with the current edition of the Service and Installation Rules of New South Wales.
2.1. **Scope**

This technical note specifies the requirements for the installation of PV power generation systems, connecting via inverters and operating in parallel with RailCorp’s distribution network, to ensure that these impacts can be controlled to maintain safe and reliable operation of the network.

There may be additional requirements over that specified in this document for installations in unique situations. These requirements shall be identified by Sydney Trains at the initial enquiry processing stage or during the processing of the connection application.

2.2. **Application**

This document applies to inverter connected PV systems, connecting to the RailCorp low voltage (LV) network.

The requirements of this technical note shall apply to all installations of inverter connected photovoltaic embedded generator systems on TfNSW facilities.

This technical note is intended to be used by Authorised Engineering Organisations (AEO) who are responsible for assuring the design, procurement, installation, commissioning and operation of any PV system.

Electrical works on RailCorp’s LV distribution system shall be carried out in accordance with standards which include, but are not necessarily limited to, those shown in Section 3 of this technical note.

3. **Reference documents**

The following documents are cited in the text. For dated references, only the cited edition applies. For undated references, the latest edition of the referenced document applies.

**Australian standards**

- AS/NZS 3000-2007 Electrical Installations (Wiring Rules)
- AS 3017-2007 Testing Guidelines
- AS 4777.2-2015 Grid Connection of Energy Systems via Inverters – Inverter requirements
- AS 5033-2014 Installation of Photovoltaic Arrays
- AS/NZS 61000.3.12-2013 Electromagnetic compatibility (EMC) – Limits – Limits for harmonic currents produced by equipment connected to public low voltage systems with input current > 16A and ≤ 75A per phase

**Transport for NSW standards**

- T HR EL 17001 ST Electrical Distribution System Installation Connection and Inspection
4. Installation and technical requirements

Section 4.1 through to Section 4.18 provides details on the installation and technical requirements.

4.1. Assessment criteria

Sydney Trains will assess the proposal for connection of the inverter based PV system based on a number of criteria. These include, but are not limited to the following:

- T HR EL 17001 ST Electrical Distribution System Installation Connection and Inspection
- network disturbances (for example, voltage and current harmonics and fluctuations)
- steady state voltage rise (on LV network, HV network or both)
- protection for anti-islanding
- total connected Embedded Generation including during daytime light load conditions on the LV and 11 kV network
- current-carrying capacity of the LV network

4.2. Inverter immunity to local supply harmonics

The RailCorp LV network contains significant harmonic distortion due to the 6 pulse and 12 pulse traction rectifiers. Refer to EP 03 00 00 01 TI Rectifier Transformer and Rectifier Characteristics for further background information.
The proponent is responsible for ensuring that the inverter system is compatible with the supply presented at each respective location.

As such, an AEO should be engaged to record the supply quality, for each location, using appropriate recording apparatus. The results of this monitoring shall form part of the assurance documentation.

4.3. **Compliance with AS 4777 Grid Connection of Energy Systems via Inverters**

Unless otherwise specified the PV system shall comply with the requirements of AS 4777.

4.4. **Clean Energy Council endorsement**

Only inverters that are either included in the list of approved inverters published by the Clean Energy Council or have been tested by an authorised testing laboratory and certified as being in compliance with AS 4777 will be accepted for connection to the RailCorp network.

4.5. **Wiring of the PV system**

The PV system shall meet the wiring requirements of AS/NZS 3000 *Electrical Installations (Wiring Rules)* and the *Service and Installation Rules of New South Wales*, with specific attention to Section 8.6. The testing of the installation for compliance with AS/NZS 3000 shall be in accordance with AS 3017 – *Testing Guidelines*.

Sydney Trains is also an inspecting authority and an installation cannot be connected to the RailCorp LV network until that work has been inspected and approved for connection by Sydney Trains or other relevant inspecting authorities as part of the mandatory inspection.

4.6. **Labelling of the PV system**

The PV system shall meet the labelling requirements outlined in the following documents:

- Clause 5.5 of AS 4777.1
- AS 5033: 2014
- *Service and Installation Rules of New South Wales*

Additional labelling requirements may be necessary in complex or unusual installations.

4.7. **Earthing of the PV system**

The AEO shall design the earthing system for the PV system to ensure compliance with the following the standards:

- AS 5033:2014
- EP 12 10 00 21 SP *Low Voltage Installations Earthing*
4.8. **Safety**

The PV system shall not impose a safety hazard to personnel working on the network, Sydney Trains customers and members of the public.

The location of the PV system isolating switches shall be accessible at all times by Sydney Trains staff and emergency services.

The design of the PV system shall include the requirements of the Sydney Trains – *Electrical Network Safety Rules* (ENSR) and consideration of the maintenance activities in accordance with ENSR.

4.9. **Permitted PV system capacity**

Currently, power generated by the PV system may only be consumed by the installation to which it is connected (that is, export is not permitted – see Section 4.13 and Section 4.14).

The following information is provided for future situations where export may be permitted.

RailCorp is limited by its network topology as to the maximum generation capacity that can be connected to a local LV network. This is largely driven by the thermal capacity of the distributor feeders, the impedance of the feeder (causing voltage rise), the distribution transformer rating and the combined effect of the connected generation plant on RailCorp network performance, operation and safety. The network study shall determine the maximum PV system capacity that can be connected (see Section 6 for information on the network technical study.) There may also be cases where the proposed system may be required to connect at a reduced capacity or where no connection is allowed.

In some instances, depending on the location of the proposed system, network augmentation and or additional protection and control functions (for either or both RailCorp network and the PV system) may be required to ensure network safety and performance standards are not compromised. Sydney Trains shall identify these as part of the network study and advise the applicant if additional work is required. The cost for some or all of this work shall be attributed to the applicant.

4.10. **Power supply reliability**

Connection of the PV system shall not create a situation where the reliability of the supply network is degraded.
4.11. **Steady state voltage**

Currently, power generated by the PV system may only be consumed by the installation to which it is connected (that is, export is not permitted – see Section 4.13 and Section 4.14).

The following information is provided as guidance for future situations where export may be permitted.

The inverter system shall be equipped with controls that enable satisfactory operation over a variation in network voltage. Installations shall be designed so that the combined impedance of the customer mains and the service mains is low enough to ensure that the generation system can export to the connection point while the voltage limits or voltage rise limits are met. Additional details and requirements are referenced in the AS 61000.3 series of documents and the ENA DOC PQ Guideline for IES connection to LV Distribution Networks.

4.12. **Power supply quality and disturbance issues**

Operation of the PV System shall not cause undue interference with the supply to other customers.

The proponent shall demonstrate compliance to power quality requirements in AS 4777.

4.13. **Prevention of export into RailCorp network**

Unless explicit approval is granted, the PV system inverter shall not export power into the RailCorp LV distribution system.

The following nominated control logic and current thresholds are designed to concurrently achieve 'no export' as well as minimise the risk of back feed from the inverter during planned and unplanned network outages.

The AEO shall provide an anti-export control circuit which connects and disconnects the inverter from the installation, via a contactor, as follows:

*Note: $I_{\text{min}}$ is the minimum measured daytime load current in any phase.*

- In normal operation the incoming supply cable load is above 5 A per phase, and the contactor is initially closed.
- If the incoming supply cable load falls below 5 A on any phase the inverters will disconnect immediately; that is, the contactor is open.
- If the incoming supply cable load increases above 5 A, but under $I_{\text{min}}$, the contactor stays open.
- If the incoming supply cable load has risen to $I_{\text{min}}$ for all phases but for less than 60 sec, the contactor remains open.
- If the incoming supply cable load remains greater than or equal to $I_{\text{min}}$ for 60 seconds, the inverters will be reconnected; that is, the contactor will close.
The incoming supply cable is the supply mains from the distribution network.

4.14. **Export into LDNSP network**

Unless explicit approval is granted otherwise, the PV system inverter shall not export power into the LDNSP network.

In addition to Sydney Trains approval, approval shall be obtained from the LDNSP (Ausgrid or Endeavour) before the PV system inverter is permitted to export power into the LDNSP network.

4.15. **Metering**

Detailed metering requirements are contained within the Service and Installation Rules of NSW and other related documents.

In general, only net metering arrangements are permissible.

Further information regarding metering arrangements should be obtained from the Electricity Contracts Delivery Manager, Sydney Trains.

4.16. **Three phase balanced inverters**

Three phase inverters shall be configured to provide a reasonably balanced output to all phases at all times whilst connected to the RailCorp network. All three phases of the inverter shall simultaneously disconnect from, or connect to the RailCorp network in response to protection or automatic controls (for example, anti-islanding and subsequent reconnection).

4.17. **Battery energy storage systems (BESS)**

The requirements for a BESS will be advised in a future ASA Standard.

4.18. **PV System connected solely to LDNSP**

Where the PV System is only connected to the LDNSP then that PV system shall meet the requirements of the LDNSP.

5. **Operation and maintenance**

Section 5.1 through to Section 5.3 describes the operation and maintenance requirements of the inverter based PV system.

5.1. **Commissioning**

Prior to the connection of the embedded generator to the RailCorp network, Sydney Trains will inspect those parts of the generation plant that have a direct effect on the network.

Where necessary, Sydney Trains may require specific tests to be carried out on the generating plant to prove the integrity of the anti-islanding and export prevention protection schemes. The
generator proponent shall develop a commissioning and test plan in conjunction with Sydney Trains.

Sydney Trains will require notice to be given to allow:

- Sydney Trains representation during commissioning and all tests that apply to Network and anti-islanding protection
- access to commissioning test results, test plans, details of test methods and protection settings
- connection to network during commissioning tests
- testing under voltage and over voltage, frequency and so on, generation system protection

Before carrying out commissioning the proponent shall provide the test procedure to Sydney Trains at least five business days prior to the appointed day for commissioning. Commissioning shall be carried out by the proponent and Sydney Trains and the commissioning dates will need to be agreed on at least three weeks prior to the commissioning taking place.

5.2. Periodic maintenance

All protection, control systems and equipment associated with the PV system and its connection to the RailCorp distribution network shall be periodically tested, in accordance with an agreed Technical Maintenance Plan developed in accordance with T MU AM 01008 ST Technical Maintenance Plans and Coding System, to demonstrate correct operation.

The owner of the PV system shall keep records of all such tests and provide Sydney Trains with a certified copy of the test results.

Failure to comply with the testing requirements may result in Sydney Trains disconnecting the PV system from the network.

5.3. Alteration to approved design

The owner of the embedded generation facility shall not modify the approved design of the PV system without informing and receiving prior written authorisation from Sydney Trains.

Settings of the protection relays and control equipment shall not be modified without informing and receiving prior written authorisation from Sydney Trains.

Upon receipt of a written request to modify the approved design or settings, Sydney Trains will advise the proponent if it is considered necessary to undertake a new assessment on the impact on RailCorp’s network, the associated costs involved and the timeframe expected to complete the study and associated report.
6. Network technical study scope

Currently, power generated by the PV system may only be consumed by the installation to which it is connected (that is, export is not permitted – see Section 4.13 and Section 4.14).

The following information is provided as guidance for future situations where export may be permitted.

The scope of the network technical study is shown in Table 1.

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Review enquiry form</td>
<td>are location, capacity, voltage, connection and timing details provided?</td>
</tr>
<tr>
<td>2</td>
<td>Check inverter compliance to AS 4777</td>
<td>CEC compliance, Manufacturer’s certificate available, AS 4777.2 compliance, Witness testing if required</td>
</tr>
<tr>
<td>3</td>
<td>Model LV network</td>
<td>obtain data on connected load - minimum, maximum estimates, or confirm network data - feeder and service type, length, substation details, model LV network including new connection downstream of distribution transformer</td>
</tr>
<tr>
<td>4</td>
<td>Network studies</td>
<td>check 11 kV feeder loading level (% thermal rating) under minimum local load demand conditions, check LV distributor loading level (% thermal rating) under minimum local load demand conditions, check distribution transformer loading level (% thermal rating) under maximum and minimum local load demand conditions, check voltage (% Vn) under minimum load at PCC, check voltage (%Vn) under maximum load at PCC, check fault Level i.e. kA at MSB and upstream of customer’s MCB, check voltage/current disturbance and harmonics against limits for compliance, check protection methodology and satisfactory operation for all types of network faults</td>
</tr>
<tr>
<td>5</td>
<td>Assess risk level of islanded operation. Increased risk if at least one of check 1 to check 4 is not met.</td>
<td>check load generation match (Sinv: Sload &lt;0.7), check [Pinv]:[Pload] &lt;0.8 or &gt;1.2, check [Qinv]:[Qload] &lt;0.8 or &gt;1.2, number of 3-ph inverters on LV feeder</td>
</tr>
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## Authorisation:

<table>
<thead>
<tr>
<th></th>
<th>Technical content prepared by</th>
<th>Checked and approved by</th>
<th>Interdisciplinary coordination checked by</th>
<th>Authorised for release</th>
</tr>
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<tbody>
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<td></td>
</tr>
<tr>
<td><strong>Name</strong></td>
<td>Neal Hook</td>
<td>Neal Hook</td>
<td>Andrea Parker</td>
<td>Graham Bradshaw</td>
</tr>
<tr>
<td><strong>Position</strong></td>
<td>Lead Electrical Engineer</td>
<td>Lead Electrical Engineer</td>
<td>Chief Engineer</td>
<td>Director Network Standards and Services</td>
</tr>
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