SAPTA

Government of South Australia
Department for Infrastructure and Transport

Traction Power Network Design and Construction – Tram System

SAPTA Asset Management

TP2-DOC-003521

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TABLE OF CONTENTS

1. Introduction

The South Australian Public Transport Authority (SAPTA) is a Directorate within the Department for Infrastructure and Transport (DIT) responsible for the delivery of public transport services.

SAPTA on behalf of the department manages the Adelaide Metropolitan Public Transport Network. As part of the execution of responsibilities of this role it must have a governance structure which includes the adoption of standards, policies and procedures.

The ATN comprises the Glenelg, Hindmarsh, East LINK and Festival Plaza tram lines. The ATN includes a diverse range of public transport assets including track, signals, communications, tram stops, traction systems, overhead wire, Electrical Engineering and rolling stock.

The Tram Network is operated and maintained by an outsourced service provider, Torrens Connect.

This standard stipulates the minimum performance and functional requirements for the traction power system for the ATN network.

2. Purpose

This standard forms part of the engineering management system is intended to ensure that the traction power system serving the ATN is not subject to any risks not deemed to meet the ‘So Far as Is Reasonably Practicable’ (SFAIRP) principles under Rail Safety National Law (RSNL).

3. Scope

The requirements of this standard apply to all existing and new traction power system installations, including all cabling and equipment from the main incoming power supply through to distribution at the pantograph interface, which includes, but not limited to:

- DC traction substations,
- Compatibility of the traction power system with rolling stock,
- Compatibility of the traction power system with other systems where interconnection is present (e.g., feeding signalling system from OHW in certain locations).
- Protective provisions against electric shock, and
- Provisions against the effect of stray current caused by DC traction system.

The scope of this document does not include:

- Rolling stock; and
- Overhead wiring system,
- Plant and Equipment linked to the traction power system, such as work platforms, wheel lathe systems)
- Signaling and telecommunications apparatus.

The intended audience for this specification includes:

- DIT Rail Maintenance functional areas,
- DIT Rail Operations functional areas.
- DIT Rail Projects; and
- DIT Rail contractors to the extent specified in their contract.

Interpretation of any technical meanings of the specifications and resolving technical disputes regarding this specification must be determined by SAPTA as the asset owner.

The tenderers/project proponents must familiarise themselves with site conditions before quoting against tenders based on this specification. Conditions particular to individual sites,

including availability of HV supply, communication cables with spare capacity, access for maintenance work, and any special conditions concerning installation and commissioning of SCADA system must be clarified in a pre-bid meeting to be arranged by the purchaser with the tenderers.

4. Related Documents

DOCUMENT NAME	DOCUMENT NUMBER
Traction Power DC substation design and construction tram system	TP2-DOC-003520
Traction Power SCADA Functional and Performance Specification – Tram System	CE2-DOC-003522
Communications Network Principles and Practices for Public Transport - Engineering Standard	AR-TP-EL-SPE-00110011
Guideline for Low Voltage Electrical Earthing and Bonding for the Adelaide Metro Tram Network	TP2-DOC-002020
Guidelines for Protective Provisions Related to Electrical Earthing & Bonding for Adelaide Metro Electrified Rail Network	AR-EL-STD-0102
Torrens Connect MOC	SQE-PRO-NIL-0006
Pit and Conduit Standard for Signalling and Communication Cables	PTS-MS-10-SG-STD-00000094
Development and Approval of Engineering Waivers	PR-AM-GE-807
Certificate of Traction Power	FO-EM-AM-1504

5. References

- Rail Safety National Law (South Australia) Act 2012
- SA Workplace Health and Safety Regulations
- South Australian Electricity Act 1966
- AS 1000 - International system of units (SI) and its application.
- AS 2067 - Substations and high voltage installations exceeding 1 kV ac
- AS 3100 - Approval and Test Specification – General Requirements for Electrical Equipment
- AS 3111 - Approval and test certification – miniature over-current Circuit Breakers
- AS 4292.4 - Railway safety management - Signalling and telecommunications systems and equipment
- AS 4312 - Atmospheric corrosivity zones in Australia
- AS 60068 (set) - Environmental Testing
- AS 60529 - Degrees of protection provided by enclosures (IP Code)
- AS 60870 (set) - Telecontrol equipment and systems
- AS 60947.2 – Low voltage switchgear and control gear – Part 2: Circuit breakers
- AS 60950.1 – Information technology equipment – Safety –General requirements
- AS 61131 (set) - Programmable Controllers
- AS 61508 (set) - Functional safety of electrical/electronic/programmable electronic safety-related systems
- AS/CA S008 - Requirements for customer cabling products
- AS/CA S009 - Installation requirements for customer cabling (Wiring Rules)
- AS/NZS 11801.1 - Information technology—Generic cabling for customer premises, Part 1: General requirements
- AS 11801.3 - Information technology - Generic cabling for customer premises, Part 3: Industrial premises
- AS 11801.5 - Information technology - Generic cabling for customer premises, Part 5: Data centres
- AS/NZS 1768 - Lightning protection
- AS/NZS 2312 - Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings
- AS/NZS 3000 - Electrical installations (the Australian/New Zealand Wiring Rules)

- AS/NZS 3008.1.1 – Electrical installations – Selection of cables – Part 1.1: cables for alternating voltages up to and including 0.6/1kV – Typical Australian installation conditions
- AS/NZS 3013 - Electrical installations – Classification of the fire and mechanical performance of wiring systems
- AS/NZS 61000.6.2 -Electromagnetic Compatibility (EMC) - Part 6.2: General standards - Immunity for industrial environments
- AS/NZS 61000.6.3 -electromagnetic Compatibility (EMC) - Part 6.3: Generic standards – Emission standard for residential, commercial and light-industrial environments
- Telecommunications Technical Standard (Surge Protective Devices for Telecommunication Applications – AS/NZS 4117) 2015
- EN 50121 (set) - Railway Electromagnetic Compatibility
- EN 50126 (set) - Railway applications - The specification and demonstration of reliability, availability, maintainability and safety (RAMS)
- EN 50128 - Railway applications. Communications, signalling and processing systems. Software for railway control and protection systems.
- EN 50159-1 - Safety related Communication in Closed Transmission Systems.
- EN 50159-2 - Safety related Communication in Open Transmission Systems.
- EN 50163 - Railway applications - Supply voltages of traction systems
- EN 50388- Railway applications - Power supply and rolling stock - Technical criteria for the coordination between power supply (substation) and rolling stock to achieve interoperability.
- EN 50124-1 - Railway applications - Insulation coordination - Part 1: Basic requirements - Clearances and creepage distances for all electrical and electronic equipment
- EN 50124-2 - Railway applications - Insulation coordination - Part 2: Over voltages and related protection
- EN 50122-1 - Railway applications – Fixed installations – Electrical safety, earthing and the return circuit – Part 1: Protective provisions against electric shock
- EN 50122-2 - Railway applications – Fixed installations – Electrical safety, earthing and the return circuit – Part 2: Provisions against the effects of stray currents caused by
- D.C. traction systems
- IEC 60870-5-104 - Telecontrol protocol IEC 61850 (set) - Substation Automation
- IEEE 1008 - Software unit testing
- IEEE 1012 - Software verification and validation plans
- IEEE 1059 - Guide for software verification and validation plans
- IEEE 802.3 - Telecommunications and information exchange between systems – Local and metropolitan area networks
- IEEE 829 - Software test documentation
- ISA 99.00.01 - Security for Industrial Automation & Control Systems
- ISA-18.2 - Management of Alarm Systems for the Process Industries
- AS/NZS ISO/IEC 27002 - Information technology – Security techniques – Code of practice for information security management

6. Compliance

All parties involved in design, construction, and modification of the ATN Trams traction power system must fully comply with this standard, the Master Specification RW series and all relevant national and international standards where applicable, the Designer must identify deviations from the above and consult these with the subject matter experts within DIT.

Deviation from this standard is only permitted when a deviation or waiver has been formally requested and approved by the Engineering Design Authority at DIT.

The Management of Change Procedure to be used is currently the one adopted by the ATN operator (at present Torrens Connect - MOC SQE-PRO-NIL-0006), this must be followed in all circumstances where change is proposed to the traction power system or to this standard.

The following definitions apply throughout the standard:

- 'Must' statements are mandatory in the context of compliance with requirements stipulated in this standard.
- 'Should' statements are considered in the context of compliance with requirements stipulated in this standard.
- 'So Far As Is Reasonably Practicable' statements must as a minimum result in the provision of a technical risk assessment including proposed list of design controls to demonstrate compliance to this standard.

Any party who is involved in the design, construction, or modification of the ATN traction power system must complete and return a statement of compliance for this standard. Assessment of compliance must be provided for each requirement, defined by one of three permissible responses:

- Compliant.
- Partially compliant; or
- Non-compliant.

Where a waiver has been determined is required, waiver process PR-AM-GE-807 must be followed.

7. Requirements

7.1. Description

At present, the ATN Trams' traction power system contains 6 traction converter substations, (one comprises two separate buildings)

South Australian Power Network (SAPN) supplies power to the ATN Trams DC traction substations, the 11kV AC supply goes through to the rectifier transformer and then via the rectifier converts the alternating current to direct current (600V DC) that supplies a bus bar and then distributed via individual circuit breakers and feeder cables, delivering power to track side section switches powering the overhead trolley wire. The return cable, known as the negative return cable, is bonded to the track via the substation negative bus bar connecting to the negative pole of the rectifier. The substation is enclosed and has fan forced ventilation to dissipate the heat generated by the transformers.

The overhead wiring is divided into different electrical sections, using section insulators. Typically, an electrical section is fed from two different traction substations and the overhead wires on adjacent tracks are connected in parallel to the same section. In many sections, an auxiliary side feeder cable is connected in parallel to the overhead wiring to increase the total cross-sectional area of the positive conductors.

The 600 V DC traction system is unearthed; the rails are not directly connected to earth, but in most cases, they are embedded in the road surface and may not be considered floating. All rails are used for the traction return current (i.e., there are no dedicated signaling rails) however on approaches to level crossing track signaling track circuits are used and there are no rail-to-rail bonds. As part of the process of DC distribution, there are various external assets that are subject to stray current damage. For this reason, the traction power system also includes components for electrolysis mitigation built into electrolysis protection systems. The HV AC and LV AC systems are earthed.

7.2. Traction Power System Requirement

7.2.1. Network Traction Power

a) The design, configuration, and operation of the ATN traction power system must ensure that it is always possible for the trams to operate

and meet the authorized design timetable requirements under N and N-1 conditions.

- The following N-1 conditions must be considered:
  - Substation rectifier outage
  - Substation Feeder Panel Failure
  - 600 V DC external isolator failure; and
  - 600 V DC positive feeder cable failure.

Information: The substation rectifier outage may be caused by events such as the loss of HV AC supply, failure of the HV AC switchgear or failure of the rectification system.

b) The traction power SCADA (Supervisory Control And Data Acquisition) system must be installed to provide remote monitoring of each substation including all alarms and fire systems where connected. The SCADA communicates through the Remote Terminal Unit (RTU) installed at separate substations.

c) An analysis of special event timetables should be undertaken to ensure satisfactory operation of the specified rolling stock fleet under such conditions.

7.2.2. Traction Power Voltage

a) Traction power voltage must comply with the following requirements of EN 50163:
   - All requirements in EN 50163 which refer to a “train” must apply for “tram” on the ATN.

In reference to section 4.1 of EN 50163 and EN 50124-2, the characteristics of the main voltage system for the ATN are specified in Table 1.

Table 1

ELECTRIFICATION SYSTEM	LOWEST NON-PERMANENT VOLTAGE U_{MIN2} [V]	LOWEST PERMANENT VOLTAGE U_{MIN1} [V]	NOMINAL VOLTAGE U_N [V]	HIGHEST PERMANENT VOLTAGE U_{MAX1} [V]	HIGHEST NON-PERMANENT VOLTAGE U_{MAX2} [V]	HIGHEST LONG- TERM OVERVOLTAGE U_{MAX3} [V]
D.C. (Mean values)	420	420	600	720	800	900

b) The traction power system insulation coordination must fully comply with EN 50124-1 and EN 50124-2.

c) The mean useful voltage at the pantograph, Umean useful, must be 540V DC in accordance with EN 50388. The following definitions must apply for Umean useful:
   - In accordance with Annex B of EN 50388, Umean useful (train) must be used and is the mean useful voltage at the pantograph of each tram taken in isolation; where only the traction periods of the tram are considered; and
   - The Umean useful (train) geographical zones must be between platforms.

7.2.3. Regenerative Breaking

a) The traction power system must be designed to permit the use of regenerative braking.

b) The regenerative braking requirements must comply with section 12 of EN 50388.

7.2.4. Rolling Stock Interoperability

a) The traction power system must comply with the following requirements of EN 50388 to ensure compatibility of the traction power system with rolling stock.
   - Any requirements which are specific to TSI lines are not applicable.
   - All requirements in EN 50388 which refer to a “train” must apply for “tram” on the ATN Trams network.

7.2.5. Electromagnetic compatibility

a) The traction power system design and configuration must comply with the electromagnetic compatibility requirements of the EN 50121 series.
b) The traction power system must comply with the following standards, regarding exposure limits for electromagnetic fields:
   - ICNIRP Guidelines: Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz); and
   - ICNIRP Guidelines: Guidelines for limiting exposure to electric fields induced by movement of the human body in a static magnetic field and by time-varying magnetic fields below 1 Hz.

7.2.6. Protection against electric shock

a) The traction power system must comply with the requirements for prevention of electric shock in EN 50122-1, except for the more stringent requirements of clause 7.2.6 (d) of this standard.
b) In accordance with Annex F of EN 50122-1, a voltage limiting device complying with EN 50122-1 must be connected between earth and the negative return circuit in each traction substation.
c) In accordance with Annex F of EN 50122-1, additional voltage limiting devices may be required in locations such as platforms. The Designer must use suitable protection equipment and ensure compliance with EN 50122-1.
d) Potential situations which may require the use of additional voltage limiting devices include, but are not limited to:
   - In reference to clause 6.2.2.1 of EN 50122-1, an exposed conductive part is located within the contact line zone or the current collector zone which is not insulated from earth and therefore has not been bonded to the return circuit, to prevent stray current corrosion. In the event of the 600 V DC contact line falling on this exposed conductive part, the part may present a hazardous voltage; and
   - In reference to section 7.1 of EN 50122-1, low voltage non traction power supplies may be endangered by the traction power return circuit.
e) The maximum permissible effective touch voltages for long-term and short-term conditions must be in accordance with the values specified in Table 2 below and must apply to all locations across the traction power system and under all normally expected operating conditions including N-1 outages.

Table 2

TIME, T [S]	$U_{TE, MAX}$ LONG-TERM [V]	$U_{TE, MAX}$ SHORT-TERM [V]
>3	60	
0.7	100	
<0.7		350
0.6		360

0.5		385
0.4		420
0.3		460
0.2		520
0.1		625
0.05		735
0.02		870
t: Time duration. $U_{te,\ max}$: Permissible effective touch voltage.		

7.2.7. Protection against stay currents

a) The traction power system must comply with:
- Guideline for Low Voltage Electrical Earthing and Bonding for the Adelaide Metro Tram Network (TP2-DOC-002020)
- Electrical Safety (Cathodic Protection) Regulations; and

b) Subject to the requirements of clause 5.2.8.1, the traction power system must comply with EN 50122-2.

7.2.8. Traction power modelling

a) Any party who is involved in the design, construction, or modification of the ATN Trams traction power system should perform a dimensioning study to assess the ability of the power supply system to achieve present and future performance.

b) This study, known as traction power modelling, must include, but is not limited to:
- Compliance with section 8 of EN 50388.
- Consideration of capacity needs for at least 20 years.
- Evidence of accuracy and, wherever possible, validation against known operational data; and
- Include infrastructure proposals which meet the performance criteria with the best value for money, where value for money is defined by the perceived CAPEX and OPEX costs of the infrastructure proposals.

Information: Power studies, or dimensioning studies of the power network, are mainly required when significant changes occur to the power network. For example, a renewal or construction of a new substation, or when the type, number or timetable of rolling stock is changed.

c) The traction power modelling must be endorsed by SAPTA.

d) The traction power modelling must include, but is not limited to, the topics and performance criteria outlined in Table 3

Table 3

TOPIC	PERFORMANCE CRITERIA	BACKGROUND	REFERENCES
Traction voltage: Pantograph to rail	U_{mean} useful (train) must not be lower than 540 V DC, during the N condition. The instantaneous2 voltage at any tram pantograph must not be lower than U_{min2}, during the N-1 condition. *Information: Where the instantaneous voltage at any tram pantograph within an electrical section is between U_{min1} and U_{min2}, during the N-1 condition, DIT must record these instances and discuss the operational risks with DoT.*	The purpose of these criteria is to ensure that trams have adequate supply voltage. The level of this supply voltage affects a tram's operational and acceleration characteristics and therefore its ability to meet a given timetable.	EN 50388 EN 50163
Rectifier capacity	The rolling RMS substation output current, calculated over a 2-hour period, must not exceed 100% of the rectifier and associated transformer capacity, during the N-1 condition[1]. The rolling RMS substation output current, calculated over a 60 second period, must not exceed 150% of the rectifier and associated transformer capacity, during the N-1 condition[1].	The purpose of these criteria is to ensure that the rectifiers and associated rectifier transformers in each substation are sized appropriately. If the equipment is overloaded beyond capacity, the equipment may trip from overtemperature and degrade the traction power system.	EN 50388 IN-021-ST-0002
Feeder DCCB and cable capacity	The rolling RMS output current of each 600 V DC feeder, calculated over a 2-hour period, must not exceed the manufacturer's capacity recommendations of the associated DCCB feeder panel or the associated feeder cable, during the N-1 condition.		EN 50388
Negative return cable capacity	As a minimum to be compliant with the Rectifier Capacity Ratings. Should also include some future proofing against the difficulty of accessing negative conductor connections to rail.		
TOPIC	**PERFORMANCE CRITERIA**	**BACKGROUND**	**REFERENCES**
Traction voltage: Rail to earth	The instantaneous[2] rail to earth voltage, U_{RE}, at any point on the traction power system must not exceed 100 V, during the N and N-1 conditions. The rolling RMS rail to earth voltage, U_{RE}, at any point on the traction power system, calculated over a 3 second period, must not exceed 60 V, during the N and N-1 conditions.	The purpose of these criteria is to ensure the safety of personnel against electric shock.	EN 50388 EN 50122-1

OHW temperature	The instantaneous temperature of the overhead wiring system[3] at any point on the traction power system must not exceed the maximum acceptable material temperatures[4], during the N-1 condition. TBC	The purpose of these criteria is to ensure: Prevention of Annealing: The overhead wiring system conductors maintain an adequate margin under their annealing temperature; and Sag: The change in length of the overhead wiring system conductors, due to changes in conductor temperature, is limited to ensure safe and reliable operation of the trams.	EN 50388 EN 50119
Sectional running times	To be in accordance with currently approved operational timetables and to also consider changes to the long-term operating plans.		
Electrolysis system	Electrolysis is not currently modelled.		

[1]This criterion is specific to rectifiers and associated rectifier transformers which have a class VI duty cycle, the most commonly seen duty cycle for the equipment in the DIT traction power system. However, this criterion must be adjusted as required according to the site-specific duty cycles of the rectifiers, associated rectifier transformers and HV AC supply capacity.
E.g., a specific substation may have class VI duty cycle equipment installed, but the HV AC supply can't provide more than 100% capacity. In this instance, the modelling performance criteria for this specific substation must be changed to reflect the HV AC supply limiting factor.
[2]Instantaneous is defined as the simulation time step of the traction power modelling software, which is typically 1 second.

7.3. Substations

Information: Design requirements for substations are described in the ATN 'Network Power – Substations'. The information presented below should be considered when completing designs for new or changes to existing substations. For complete guidance on substation requirements, refer to the 'Network Power – Substations'.

7.3.1. Design and configuration considerations

a) Before a DC traction substation design can commence, a system level design should be completed. The system level design must include the following as a minimum:
- Existing traction power system:
- Evidence of non-compliance of the electrical sections, using references to clauses in this standard; and
- Traction power modelling of the existing traction power system, evidence of non-compliance.
- Traction power system with proposed substation configuration:
- Evidence that the proposed solutions will bring the non-compliant electrical sections into compliance.
- Traction power modelling of the traction power system with the proposed substation, evidencing that the proposed solutions will bring the non-compliant electrical sections into compliance.
- The high-level configuration of equipment within the substation including a single line diagram showing the quantities and ratings of incoming supplies, rectifiers, 600 V DC feeder panels as well as how the equipment must be interconnected.
- 600 V DC sectionalizing arrangements.

- Details of the Distribution Network Service Provider that will supply the HV AC power.
- The required size and quantity of 600 V DC feeder cables.
- The required size and quantity of negative feeder cables; and
- The geographical location and physical size of the substation.
- Substation acceptance criteria:
- Acceptance criteria for the proposed substation; and
- A high-level test methodology for evidencing the acceptance criteria.
- Operational Fleet profiles based on confirmed operational timetables and fleet type.

Information: The system level design provides the necessary information for the Scope of Works to be prepared.

b) The Designer must consider the following when determining the geographical location of the substation:
   - Availability of incoming HV AC supply.
   - Electrical sectioning – location of 600 V DC overhead sectioning point (the existing sectioning points may have to be changed to facilitate the location of sectioning points adjacent to substations).
   - Site access - all weather heavy vehicle access for construction and future maintenance requirements.
   - Space availability and site topography.
   - Location from track and orientation to track.
   - Amenities – require stormwater and sewerage connections.
   - Security considerations.
   - Susceptance of site to adverse weather conditions; and
   - Site specific environmental requirements and considerations.

7.4. Traction power conduits and pits

- For the traction power network parallel feeders, a minimum of 3 separate conduits of at least 150mm diameter must be installed.
- For the SCADA and general communication network, a minimum of 2 separate conduits of 100mm diameter must be installed,
- Refer to section 13.3 of PTS-MS-10-SG-STD-00000094 for Pit minimum dimensions requirements.
- Refer to section 13.4 of PTS-MS-10-SG-STD-00000094 for Pit location requirements.

7.5. Tram/Train interfaces on ATN

No Tram/train interfaces at road crossings are present in the current network, in the only two existing crossings the tram tracks are on an overpass above the rail line (at Goodwood train station and on the Port Road bridge).

For any future tram/train interface follow requirements in ‘Guidelines for the Protective Provisions Related to Electrical Earthing and Bonding for the Adelaide Metro Electrified Rail Network’, doc. AR-EL-STD-0102 and ‘Guideline for Low Voltage Electrical Earthing and Bonding for the Adelaide Metro Tram Network doc. TP2-DOC-002020.

8. Traction power system test methodology

8.1. Commissioning testing

The project/main contractor must conduct commissioning test Upon completion of any addition/modification to traction power system.

Project-specific ITP's must document commissioning test procedures for verification of system functionality and must be endorsed by the designer and the Manager Electrical Engineering (or his nominee) before the conduct of the relevant tests.

Commissioning testing will include testing of voltages and currents in the modified traction power system.

8.2. System integration testing

System Integration Testing must verify the functionality and performance of the traction power system in response to the highly variable and potentially severe conditions on an operational railway. SIT must only commence after all project-specific works (e.g., including rolling stock, if relevant) have been completed, tested and commissioned.

System Integration Tests typically include:

- Testing of the stability and reliability of the traction power system and associated TPSS during operational tests of rolling stock under widely varying headway and tram loading conditions, generating varying voltages, currents, and harmonics throughout the traction power system.
- TPSS response and recovery to stress tests / failure events induced on traction power and TPSS equipment, subsystems, and systems (e.g., Short-circuit testing of the traction power system)
- Electromagnetic emissions compliance testing on the railway as a whole and at traction power substations (per EN50121).
    - Testing of Stray currents and electrolysis prevention systems in affected area
    - Testing of rail voltages (including operation of voltage limiting devices)

Upon completion of the above testing and all other applicable testing, the project/main contractor must issue a compliance certificate (refer to section 4 for document details).