Government of South Australia
Department for Infrastructure and Transport

Tram System – Overhead Wiring System Requirements for the 600v DC Tram Network

Engineering Standard

Asset Management/Rail Commissioner

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TABLE OF CONTENTS

1. Introduction 5
2. Purpose 5
3. Scope 5
4. Related Documents 5
5. References 5
6. Compliance 6
7. General 6
8. Climatic Conditions 6
9. Mechanical Requirements 7
   9.1. Projected Life 7
   9.2. Corrosion Prevention 7
   9.3. Water Resistance 7
   9.4. Use of Composite Materials 7
   9.5. Factors of Safety 7
10. Electrical Requirements 7
   10.1. Earthing and Bonding 7
   10.2. Conductor Size 7
      10.2.1. Determination 7
      10.2.2. Standard Feeder Conductor Size 7
   10.3. Insulation Levels 8
   10.4. Electrical Clearances 8
   10.5. Current Carry Capacity 8
   10.6. Cleaning and Greasing of Current Carrying Connections 8
11. Overhead Wiring Geometry Requirements 8
   11.1. Types of Trams 8
   11.2. Contact Wire Height 9
   11.3. Contact Wire Stagger 9
   11.4. Current Collection 9
   11.5. Contact Wire Sag 9
12. Infrastructure Requirements 9
   12.1. Poles 9
   12.2. Footings 10
   12.3. Contact Wire Supports 10
   12.4. Tension Lengths 11
   12.5. Tensioning Devices 11
   12.6. Electrical Sectioning 11

12.7. Surge Diverters 11
12.8. Crossings 11
12.9. Jumpers 12
12.10. Numbering 12
12.10.1. Pole Numbers 12
12.10.2. Switch Numbers 12
12.11. Connections Between Buried Feeder Cable and Overhead Wiring Equipment 12
13. Drawings 13
14. Competencies 13

1. Introduction

The Overhead Wiring System (OHW) transmits electric power to trams from lineside convertor stations, a type of electrical substation.

2. Purpose

The purpose of this standard is to describe the technical requirements for the Tram OHW on the Adelaide Metropolitan Passenger Rail Network (AMPRN).

This standard must be read in conjunction with the tram system standards listed in section 4 and the Department of Infrastructure and Transport (DIT) Master Specifications.

3. Scope

This standard applies to all new projects that involve OHW and any modifications to existing OHW. It also applies to maintenance activities, though it is not intended that the maintainer modifies the existing OHW equipment to be compliant with this standard.

4. Related Documents

DOCUMENT NAME	DOCUMENT NUMBER
Guideline for Low Voltage Electrical Earthing and Bonding for the Adelaide Metro Tram Network	TP2-DOC-002020
Einholmstromabenehmer Pantograph - (*Drawing)*	1Fb700.300
Schunk Pantograph - (*Drawing)*	1-7020.5710
Minimum Structural Outline – General Layout (Drawing)	CS2-DRG-365078
Drafting Requirements for SAPTA drawings	AM5-DOC-003408
Glenelg Line Section 1 Tension Length Diagram - (*Drawing)*	TP2-DRG-000397
Glenelg tramline Morphettville Racecourse to Tram Depot Poles G276 – G284 Overhead Wiring Layout - (*Drawing)*	417-A1-2009
Hindmarsh Tramline, North Terrace to Adelaide Entertainment Centre, Centre Pole H41 cross section - (*Drawing)*	1-6924-2256
Hindmarsh Tramline, North Terrace to Adelaide Entertainment Centre, Centre Pole H41 cross section - (*Drawing)*	1-6924-2257
Symbols for use on Minor Sectioning Diagrams - (*Drawing)*	TP2-DRG-000077
Minor sectioning Diagram – Entertainment Centre Extension - (*Drawing)*	665-A3-08-12
Traction Power Network Design and Construction – Tram System	TP2-DOC-003521
Traction Power DC substation design and construction tram system	TP2-DOC-003520
Elektroline Catalogue	https://www.elektroline.cz/catalogue_list.php
Master Spec, Overhead Wiring	RW-OHW-D1

5. References

- *South Australian Electricity Act*
- *SA Electrical Regulations 2012*
- *EN50125 Part 3 2003: Railway Applications Environmental Conditions for Equipment*
- *AS/NZS 4600 2018: Cold-Formed Steel Structure*
- *AS/NZS 1170.0 2002: Structural Design Actions*
- *AS/NZS 1170.2 2021: Structural Design Wind Actions*
- *AS/NZS 1214 2016: Hot-Dip Galvanised Coatings on Threaded Fastners*
- *EN 50163 2020: Supply Voltage of Traction Systems*
- *AS 3000 2018: Electrical Installations*
- *AS/NZS 4792 2006: Hot-Dip Galvanised Coatings*

- *AS/NZS 1163 2016: Cold formed Steel Hollow Sections*
- *AS/NZS 1554 2014: Structural Steel Welding*
- *EN 50317:2012 Railway Applications – Current Collection Systems. Requirements for and Validation of Measurements of the Dynamic Interaction between Pantograph and Overhead Contact Line*
- *EN 50367:2020 Railway Applications – Current Collection Systems – Technical Criteria for the Interaction between Pantograph and Overhead Contact Line*

6. Compliance

There are 3 types of provisions contained within this standard:
1. Requirements
2. Recommendations
3. Permissions

Requirements – it is mandatory to follow all requirements to claim full compliance with the standard. Requirements are identified within the text by the term '**must**'.

Recommendations – do not mention or exclude other possibilities but do offer the one that is preferred. Recommendations are identified within the text by the term '**should**'. Recommendations recognise that there could be limitations to the universal application of the control, i.e. the identified control is not able to be applied or other controls are more appropriate or better.

Permissions – conveys consent by providing an allowable option. Permissions are identified within the text by the term '**may**'.

Deviation from a mandatory requirement noted within this standard is only permitted when an Engineering Waiver has been provided to and approved by the Department's Rail Asset Management Group.

7. General

- The existing OHW consists of a single 107mm^2 conductor wire supported by insulated fittings, utilising items from the Elektroline catalogue. The insulated fittings are mounted on steel poles supported by concrete footings. There is a mixture of fixed and regulated equipment along the route.
- The OHW is electrically supported by 400mm^2 buried feeder cables that run the length the length of the Tram network and is connected to the contact wire through tap to trolley connections at regular intervals.
- The contact wire and feeder are supplied with a nominal 600V DC (Direct Current) supply from six converter stations along the route of the tramway. The overhead system is split into separate electrical sections using insulated overlaps or section insulators, which can be controlled using lineside switches or circuit breakers in the convertor stations.
- Any new or modified equipment must be compatible with the existing equipment.

8. Climatic Conditions

The OHW system should be designed to operate between -5°C and +55°C.

Environmental Conditions should be based on EN50125 Part 3 2003: Railway Applications Environmental Conditions for Equipment.

Wind loading on OHW equipment and support structures should be determined in accordance with *AS/NZS 1170.0 2002*: Structure Design Actions – general principles and *AS/NZS 1170.2 2021*: Structural Design Actions – Wind Actions.

Regional wind speeds must be modified in accordance with *AS/NZS 1170.2 2021* for design factors such as wind direction, terrain/height, shielding and topographical multipliers.

9. Mechanical Requirements

9.1. Projected Life

Overhead fittings and systems should be designed for a minimum service life of 30 years. Poles and footings that support the overhead line fitting should be designed for a minimum service life of 50 years.

9.2. Corrosion Prevention

Corrosion resistant metals or adequate long term corrosion protection should be provided in so far as dissimilar metals which would promote galvanic corrosion must not be used in proximity to each other.

All ferrous parts should be hot dip galvanised upon completion of fabrication, including nuts, bolts and washers. Refer to *AS/NZS 4792 2006* and *AS/NZS 1214 2016*.

9.3. Water Resistance

The overhead fitting should be constructed from material and in such a manner to provide projected life delivery in service.

9.4. Use of Composite Materials

- Composite materials must be stable in Ultra-Violet (UV) Radiation.
- Composite materials must be resistant to chemicals that might be encountered in their environment and must provide adequate electric insulation levels.
- Composite materials must not sustain combustion.
- Composite materials must have good wear characteristics if subject to wear and be capable of withstanding electrical arcing without deterioration.
- Composite materials must have low moisture absorption characteristics.
- Composite materials must have a high impact resistance.
- Composite materials must not be used where they are liable to be damaged by birds.

9.5. Factors of Safety

- A loading safety factor of 3:1 must apply to all supporting structures.
- Contact wire must have a factor of safety at least 2.5:1 on worn wire with 30% Cross Sectional Area (CSA) removed at maximum working tension.

10. Electrical Requirements

All electrical components that make up all the tramway OHW must be rated to 600V according to EN50163 2020.

10.1. Earthing and Bonding

Bonds and earthing must be in accordance with the document *Guideline for Low Voltage Electrical Earthing and Bonding for the Adelaide Metro Tram Network TP2-DOC-002020.*

10.2. Conductor Size

10.2.1. Determination

Conductor sizes should be determined by both mechanical and electrical ratings, protection and strength considerations.

10.2.2. Standard Feeder Conductor Size

The standard feeder conductor size used on the Adelaide Tram Network are listed below and should be used where suitable.

Table 1 Standard feeder conductor size

DESCRIPTION	NOMINAL CSA	CONDUCTOR MATERIAL	CONSTRUCTION SIZE	NOMINAL OUTSIDE DIAMETER (OD)	REMARKS
Contact Wire	107mm^2	Hard Drawn (HD) Copper	Solid	12.34mm	Bare
Feeder tap to trolley continuity jumper	185mm^2	Annealed Copper	5510mm/0.2mm	31.6mm	UV Resist rubber 0.6/1kV insulated
Surge divertor cable	70 (equivalent) Eqv	Annealed Copper	19mm/2.14mm	13.5mm	UV Resist rubber 0.6/1kV insulated
Buried feeder cable	400 Eqv	Annealed Copper	61mm/2.85mm or suitable for requirement bending radius	39mm	Cross Linked Polyethylene (XPLE) Insulated 37 wire screen, Polyvinal Chloride (PVC) sheath

10.3. Insulation Levels

- All insulators must be rated for operation at 1000v as a minimum
- All attachments to poles and other structures must be at least double insulated from live parts.
- All supports spans must be insulated in such a manner that should they break live parts will be maintained at a height not less than 3 metres above ground level.
- Electrical installations mounted on or suspended off tram poles, such as Closed-Circuit Television (CCTV) cameras, light luminaries, mobile phone or Wi-Fi antennas and Telecommunication infrastructure must be double insulated and comply with *AS3000 2018*.

10.4. Electrical Clearances

All electrical clearances from any conductor or part energised at 600V DC must be in accordance with the Electrical Safety Act, South Australia (SA) Electrical Regulations and South Australian Power Network (SAPN) service installation rules.

10.5. Current Carry Capacity

The current carrying capacity of switches or isolators must not be less than that of the highest rated conductor(s) connected to each of its terminals.

10.6. Cleaning and Greasing of Current Carrying Connections

All joint assemblies which are designed to permit the transfer of current from one conductor to another are to be prepared cleaned and greased with a suitable electrical joining compound in accordance with manufacturer's instructions.

11. Overhead Wiring Geometry Requirements

11.1. Types of Trams

The tram OHW in AMPRN only supports the use of pantograph collection systems. Two types of trams operate at the network.

- Bombardier Flexity Classic Trams fitted with a Einholmstromabenehmer pantograph. Details are available on drawing *1Fb700.300.*
- Alstom Citadis 302 Trams fitted with a Schunk pantograph. Details are available on drawing *1-7020.5710.*

11.2. Contact Wire Height

a) The maximum contact wire height must not exceed 5.8m.
b) The minimum contact wire height at road intersections must not be less than 5.66m, including sag.
c) The minimum Contact Wire height excluding road intersections should not be less than 5.0m, including sag.
d) The contact wire height in depots should be 5.8m at supports.
e) The normal contact wire height at supports should be 5.6m.

11.3. Contact Wire Stagger

a) The contact wire must be staggered to ensure that the contact wire remains on the pantograph under worse conditions including, blow off, vehicle sway and include an allowance for maintenance tolerances of 30mm. Under normal circumstances the contact wire should only interact with the portion of the pantograph fitted with carbon strips.
b) On tangent track the contact wire stagger should alternate on either side of the centre line of the track in a zigzag pattern reaching a maximum offset of 230 mm from the centreline of the track at supporting structure.
c) On curved track the contact wires should be staggered to a maximum of 300 mm from the centre line of the track towards the outside of the curve.
d) The contact wire should be staggered to achieve a minimum sweep ratio of 5 mm of across track movement across the pantograph for every 1 metre of travel along track. Note that the requirements at 11.3.(a). 11.3.(b). and 11.3.(c). takes priority over 11.3.(d).

11.4. Current Collection

Loss of contact between the pantograph and the contact wire must not exceed 0.5% at normal service speed. The interaction between the tram Pantograph and the OHW must be in accordance with EN 50367:2012 Railway Applications – Current Collection Systems – Technical Criteria for the Interaction between Pantograph and Overhead Contact Line and EN 50317:2020 Railway Applications – Current Collection Systems. Requirements for and the Validation of the Dynamic Interaction between Pantograph and Overhead Contact Line.
Dramatic changes in contact wire level can cause loss of contact.

- The maximum contact wire gradient between support structures relative to track levels should not exceed a gradient of 1 in (5X line speed in kmh).
- Any changes in direction of gradients should be separated by a span of contact wire at zero gradient.

11.5. Contact Wire Sag

Contact wire sag will be determined by the tension of the contact wire, the distance between supporting structures and for fixed equipment the temperature.

- Contact wire sag must be managed to ensure satisfactory current collection between pantograph and contact wire.
- Contact wire sag must be managed to ensure that the minimum height stated in 11.2.(b). and 11.2.(c). are always achieved.

12. Infrastructure Requirements

12.1. Poles

All poles and footings supporting the OHW must be clear of the tram Kinematic envelope. Refer to drawing *CS2-DRG-365078, Minimum Structural Outline – General Layout.*

Existing poles are rated by load capacity and overall length expressed in kilo newton metres (kN/m), that is, 4/12 is a pole rated at 4kN/12m long.

Poles are comprised of two sections of Circular Hollow Sections (CHS) welded together. Typical sections are:

- 219mm CHS 8.2mm wall
- 273mm CHS 9.3mm wall
- 324mm CHS 12.7mm wall

Table 2 Typical Pole Types

	BASE CHS PROPERTIES			TOP CHS PROPERTIES			
Type	**Dia**	**Wall**	**Length**	**Dia**	**Wall**	**Length**	**Typical Use**
4kN/12m	219mm	8.2mm	1200mm	-	-	-	Cantilever
6.5kN/12m	273mm	9.3mm	7000mm	219mm	8.2mm	5000mm	Overlap and midpoint anchor (MPA) centre pole
17kN/13m	324mm	12.7mm	8000mm	273mm	9.3mm	6000mm	Termination Pole
6.5kN/12m	273mm	9.3mm	7000mm	219mm	8.2mm	5000mm	Headspan

Poles should be;

- Fitted with a cap.
- Hot dip galvanized to *AS/NSZ 4792:2006*.
- Constructed from two diameters (Dia) of CHS tube complying with *AS/NZS 1163*:2016, Cold formed Structural Steel Hollow Sections.
- Structural Steel plate must be grade 250 and yield stress not less than 340 mega pascals (MPa).
- All welding must comply with *AS/NZS 1554:2014* SET Structural Steel Welding Set.
- Be plated with a stamped panel recording, manufacturer, date of manufacture and Pole rating type.

New and replacement poles should match the existing poles.

Consideration for signal sighting, traffic signal sighting and crossing sighting must be taken account of when placing poles, in accordance with *CS4-DOC-000446, Standard for Railway Pedestrian Crossings and SG2-DOC-002021, Practices and Requirements for Tramline Signaling on the Adelaide Tram Network.*

12.2. Footings

Typical existing pole footings are 600mm dia bored side bearing type with 25MPa concrete.

The footing depth is determined by the mast loading, soil type and measured effective depth.

To prevent corrosion from contamination around the interface of the footing and pole, a concrete muff is to be cast with the footing. This should be clear of the ground or nominal ballast level by a minimum of 200mm and have a trowelled watershed.

12.3. Contact Wire Supports

The contact wire may be supported by cantilevers or headspans as appropriate. The supports should be an elasticated arrangement from the Elektroline catalogue.

In Auto Tensioned areas the support must allow for along track movement throughout the temperature range.

Contact wire supports should have an adjustment range of +/- 200mm for height and +/- 100mm for stagger from the design values.

12.4. Tension Lengths

On mainline areas Auto Tension Lengths with Tension devices at either end and a MPA in the centre should be used.

Fixed equipment may be utilised if tight curves or complicated track arrangements mean that Auto tension equipment is not suitable.

The maximum ½ tension length must not exceed 700m. The ½ tension length should be reduced where required such that the tension loss due to drag does not exceed 7% or if the stagger limits stated in section 11.3 cannot be met across the temperature operating range.

The interface between Auto tensioned equipment and Fixed equipment should be at an overlap, with additional support structures on the fixed equipment to ensure a smooth pantograph passage. A MPA arrangement may be used to transit between fixed and Auto tensioned equipment if it is impractical to install an overlap.

Contact Wire Splices must not be used in a tension length on new installations.

12.5. Tensioning Devices

- Pfisterer Spring Tensioners may be used in shared corridor or closed corridor areas.
- Balance weights with the weight stacks contained inside of the pole may be used in shared corridor or closed corridor areas.
- Balance weights mounted external to the pole may only be used in the closed corridor areas.

12.6. Electrical Sectioning

The OHW must be divided into discrete electrical subsections. Each subsection should be capable of being isolated as a single unit. The sub sectioning should take into account the operational requirements, the signaling layout, the track layout and the electrical isolation requirements. The sectioning proposals must be agreed with the Department's Rail Asset Management Group.

The OHW should use insulated overlaps to create the sectioning points. Section insulators may be used if it is not practical to use an insulated overlap. Currently the system uses Arthur Flury FTBM1 section insulators.

Section insulators must not be positioned in a location where they will be bridged by a stationary pantograph during normal operational service, eg at signals, tram stops or traffic intersections.

12.7. Surge Diverters

Surge divertors should be used to protect underground cables and convertor station equipment and as such must be fitted at all Tap to Trolley locations.

Surge Diverter Characteristics:

- Rated voltage, 1kV/ 2kV DC
- Nominal discharge current, 10kA
- Permissible short circuit 20kA / 0.2 seconds

12.8. Crossings

At points and crossings, the supporting pole should be placed at 300mm point opening. A cross contact bar must be fitted where the two contact wires cross.

Where two tracks cross at an angle of 55° to 90°, then a Kunnler & Matter Kudisc should be used.

12.9. Jumpers

Continuity jumpers must be fitted between adjacent contact wires at overlaps and crossings. The jumper must allow for the along track movement of the two contact wires throughout the temperature range.

A Track to Track equalizing jumper must be fitted in two track areas where both tracks are the same subsection. The jumper connects the two contact wires and should be installed every 5 spans or at a frequency determined by the designer.

Currently 185mm² cable is used for these jumpers.

12.10. Numbering

12.10.1. Pole Numbers

Each OHW Pole must have a unique number. The number is to have an Alphabetic prefix designating the route, then a sequential number indicating the number of the pole. If the pole is part of a head span structure the pole on the upside should have a U suffix and the pole on the downside should have a D suffix.

Currently;

- G prefix is the Glenelg line.
- H prefix is the Hindmarsh line.
- P prefix is the Festival Plaza line.
- M prefix is the Botanic Gardens line.

If a new pole is to be installed in between two existing poles the new pole must adopt the previous pole number with an alphabetic suffix. E.g., if a new pole is to be installed between poles G15 and G16 the new pole should be numbered G15A.

A circular blue sticker with white figures showing the pole number should be installed on every pole, 3m above rail level, facing on coming trams.

12.10.2. Switch Numbers

Each lineside switch is to have a unique number as indicated on the Minor Sectioning Diagram. The switch number consists of two numbers, the first number shows the Electrical section number, and the second number shows the sequential number of that switch in the electrical section. E.g., switch 21/8 is the 8th switch in electric section 21.

A switch number plate, showing the switch number, with black numbers on a white background should be attached to every pole supporting a lineside switch.

12.11. Connections Between Buried Feeder Cable and Overhead Wiring Equipment

Connections between the buried feeder cable are made through a switched or un switched Tap to Trolley.

All connections to the buried feeder cable should be at the top of Tap to trolley poles or in above ground pillar boxes. Connections must not be made in underground pits.

13. Drawings

The following drawings must be created or updated, as required, when making modifications or additions to the OHW. Drawings should follow *AM5-DOC-003408, Drafting Requirements for SAPTA Drawings.*

- Tension Length Diagram, a schematic showing the tension lengths along a route. Refer to drawing *TP2-DRG-000397* as an example.
- Layout Plan, A scale plan that shows the position of tracks, poles and wire runs, anchors, section insulators, jumpers, in span insulation, switches and buried feeder cable route. The layout plan should also show tram stops, bridges, crossings and signals. Information boxes should show pole numbers, kilometrage, heights, staggers, span lengths and support type where a standard support is used. Refer to drawing *417-A1-2009* for an example. Colours must be used to help distinguish different wire runs and wire runs from rails.
- Cross sections for individual pole should be produced if a non-standard type of support is used. Refer to drawing *1-6924-2256* and *1-6924-2257* as an example.
- Minor Sectioning Diagrams show an electrical schematic of the overhead wiring system including convertor stations, buried feeder cable, switches, jumpers, circuit breaker numbers, switch number, section numbers and sub section numbers. Drawing *TP2-DRG-000077, "Symbols for use on Minor Sectioning Diagrams"* shows the symbols to be used. Refer to drawing *665-A3-08-12* as an example of a minor sectioning diagram.

14. Competencies

Any group carrying out design, installation or maintenance works on the Adelaide tram OHW must prove their competency on overhead wiring equipment to the satisfaction of the Department's Rail Asset Management Group. Competency can be demonstrated through past experiences, qualifications and references.