Direct Current Traction Power Reticulation

Version 2.0

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Standard governance

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### Document history

<table>
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<tr>
<th>Version</th>
<th>Summary of changes</th>
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<tr>
<td>1.0</td>
<td>First issue 25 May 2017.</td>
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<tr>
<td>2.0</td>
<td>Addition of a current rating criteria for traction power reticulation cables. New requirements for traction power reticulation cable containment; HV aerial crossing; bonding, durability and aesthetics of OLE poles; overhead contact charging conductor.</td>
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Preface

The Asset Standards Authority (ASA) is a key strategic branch of Transport for NSW (TfNSW). As the network design and standards authority for NSW Transport Assets, as specified in the ASA Charter, the ASA identifies, selects, develops, publishes, maintains and controls a suite of requirements documents on behalf of TfNSW, the asset owner.

The ASA deploys TfNSW requirements for asset and safety assurance by creating and managing TfNSW’s governance models, documents and processes. To achieve this, the ASA focuses on four primary tasks:

- publishing and managing TfNSW’s process and requirements documents including TfNSW plans, standards, manuals and guides
- deploying TfNSW’s Authorised Engineering Organisation (AEO) framework
- continuously improving TfNSW’s Asset Management Framework
- collaborating with the Transport cluster and industry through open engagement

The AEO framework authorises engineering organisations to supply and provide asset related products and services to TfNSW. It works to assure the safety, quality and fitness for purpose of those products and services over the asset’s whole-of-life. AEOs are expected to demonstrate how they have applied the requirements of ASA documents, including TfNSW plans, standards and guides, when delivering assets and related services for TfNSW.

Compliance with ASA requirements by itself is not sufficient to ensure satisfactory outcomes for NSW Transport Assets. The ASA expects that professional judgement be used by competent personnel when using ASA requirements to produce those outcomes.

About this document

This standard sets out the requirements for the configuration and performance of the direct current traction power reticulation systems providing the connectivity between the traction power substations and the light rail vehicles (LRVs) of a light rail system.

This document is the second issue. The changes from the previous version include the following:

- addition of a current rating criteria for traction power reticulation cables
- new requirements for:
  - traction power reticulation cable containment
  - high voltage (HV) aerial crossing
  - bonding, durability and aesthetics of overhead line equipment (OLE) poles
  - overhead contact charging conductor

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1. **Introduction**

Light rail vehicles (LRVs) and traction substations are connected with the direct current (dc) traction power reticulation system which is comprised of the following:

- traction power feeder cables
- overhead conductor system (OCS) or segmented third rail system
- traction return conductors

An OCS can consist of the following:

- overhead line equipment (OLE)
- overhead conductor rail system

The traction voltage level is such that contact by persons will cause serious injury or death. In addition, the traction voltage is reticulated in the public domain using bare conductors to which the LRVs make contact. Accordingly, it is essential that a light rail traction power system is configured and operated to ensure safety.

2. **Purpose**

The purpose of this standard is to set out the requirements for the configuration and performance of the dc traction power reticulation system and its elements to ensure safe and reliable operation.

2.1. **Scope**

This document sets out the technical requirements for the dc traction power reticulation system and its elements.

This document excludes all aspects of the running rails except only so far as they function as traction return conductors.

2.2. **Application**

This standard is applicable to all new dc traction power reticulation systems.

This standard is also applicable to the modification of existing dc traction power reticulation systems.

Where a new dc traction power reticulation system or modification is constructed and energised in stages, the requirements of this standard are applicable to the configuration at each stage of construction.

Unless otherwise stated, application is not retrospective to existing infrastructure which is not otherwise being altered.
This standard is intended to be used by competent personnel engaged in the provision of services relating to light rail infrastructure. In addition to the requirements of this standard, asset decisions take into account the life cycle cost considerations specified in T MU AM 01001 ST Life Cycle Costing.

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.

**International standards**

EN 50119 Railway applications - Fixed installations - Electric traction overhead contact lines
EN 50122-1 Railway applications - Fixed installations - Electrical safety, earthing and the return circuit - Part 1: Protective provisions against electric shock
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: Overvoltages and related protection
EN 50345 Railway applications - Fixed installations - Electric traction - Insulating synthetic rope assemblies for support of overhead contact lines
EN 50367:2012 Railway applications - Current collection systems - Technical criteria for the interaction between pantograph and overhead line (to achieve free access)
EN 61140 Protection against electric shock – Common aspects for installation and equipment

**Australian standards**

AS 2159 Piling – Design and installation
AS 4100 Steel structures
AS/NZS 1170 (all parts) Structural design actions
AS/NZS 1768 Lightning protection
AS/NZS 4680 Hot-dip galvanized (zinc) coatings on fabricated ferrous articles
AS/NZS 5000.1 Electric cables – Polymeric insulated Part 1: For working voltages up to and including 0.6/1 (1.2) kV
AS/NZS 7000 Overhead line design

**Transport for NSW standards**

EP 00 00 00 13 SP Electrical Power Equipment – Design Ranges of Ambient Conditions
EP 20 00 00 03 SP Above Ground Cable Installation Systems - Selection Guide
EP 20 00 04 01 SP Cable Route Selection Guide
EP 20 00 04 04 SP Ground Entry Arrangements
EP 20 00 04 05 SP Cable Pits
EP 20 00 04 06 SP Underground Cable - Location Recording
T HR EL 20003 ST Underground Installation Configurations for High Voltage and 1500 V dc Cables
T LR CI 12500 ST Civil Infrastructure Design Standards
T LR CI 12520 ST Civil Infrastructure Construction
T LR CI 12530 ST Corridor Interface Requirements
T LR EL 00001 ST Traction Power System Requirements
T LR EL 00007 ST Traction Power Supply Infrastructure and Light Rail Vehicle Interface
T LR RS 00100 ST LRU 100 Series – Minimum Operating Standards for Light Rail Vehicles – General Interface Standards
T LR TR 10000 ST Light Rail Track Requirements
T MU AM 01001 ST Life Cycle Costing

Other reference documents
Alstom, SLR-ALS-D50-RST-SPE-000156 Sydney Light Rail- Interface Specification Rolling Stock / Power Supply (available on request from standards@transport.nsw.gov.au)

4. Terms and definitions

The following terms and definitions apply in this document:

**APS** aesthetic power system

**IP** ingress protection rating

**LRV** light rail vehicle

**OCS** overhead conductor system

**OHW** overhead wiring

**OLE** overhead line equipment

**SFAIRP** so far as is reasonably practicable
5. **Traction power reticulation sectioning and connectivity**

5.1. **Sectioning**

The traction power reticulation shall be sectioned to accommodate all proposed operational modes and required contingencies.

The OLE system shall be sectioned at each traction power substation location and other locations as necessary.

5.2. **Open overlaps**

An overlap is the overlapping of the ends of two lengths of overhead line conductors, arranged in such a manner that the pantographs of a LRV can pass smoothly and without breaking contact from one contact wire to the next over the same track.

An open overlap is an overlap in which the wire-runs forming the overlap are of different electrical sections or subsections.

If an open overlap is bridged by a stationary pantograph, and if the electrical section on one side of the overlap is tripped, then current feeds into the tripped section through the pantograph. This has previously resulted in the contact wire being burned through.

Open overlaps shall be positioned clear of areas where LRVs would normally stop.

5.3. **Insulated rail joints**

Where insulated rail joints are provided to separate earthed and un-earthed portions of the traction power system, the corresponding points of separation in the positive circuit shall be aligned with the insulated rail joints. This ensures that wherever there is a 750 V positive supply available, there is also a traction return path to the substation negative available.

Suitable controls shall be provided to prevent the sections from being bridged by a LRV when one of the sections is isolated.

5.4. **Arrangements for double track sections**

The traction power reticulation for both tracks of double track sections may be electrically connected in parallel. If so, the traction power reticulation for both tracks of double track sections shall be connected together, as well as to any helper cables at feeding locations, and at sufficient intermediate points as necessary to reasonably limit voltage drop and loop resistance.
5.5. **Stabling areas**

In order to ensure that a single electrical fault does not 'trap' an excessive number of LRVs, the traction power reticulation for stabling areas shall be sectioned so that each switchable subsection supplies the stabling area for no more than six LRVs.

5.6. **Maintenance areas**

In order to ensure that an electrical fault in the maintenance area does not affect the stabling area, the traction power reticulation for maintenance areas shall be a separate switchable section from the stabling areas and should preferably be fed from a separate direct current circuit breaker (DCCB).

On networks that use in-ground power supply systems, a test section of the equipment shall be provided at any location where LRV maintenance facilities are provided. The test section shall be accessible from the LRV maintenance facilities even when all the stabling berths are occupied.

6. **Traction power reticulation cables specification**

All 750 V positive cables shall be 0.6/1 (1.2) kV single core insulated and be sheathed in accordance with AS/NZS 5000.1 *Electric cables – Polymeric insulated Part 1: For working voltages up to and including 0.6/1 (1.2) kV*.

Cables shall also have the following characteristics:

- Conductor – stranded copper.
- Insulation – cross-linked polyethylene (XLPE) or ethylene propylene rubber (EPR). However, reduced fire hazard cable material suitable for up to a 90 °C maximum continuous operating temperature in accordance with AS/NZS 5000.1 shall be used for cables in tunnels, underground stops and underground substations.
- Polymeric oversheath providing adequate protection against mechanical damage for the designed construction method and site environment.

All 750 V positive cables shall have double insulation complying with class II equipment in accordance with EN 61140 *Protection against electric shock – Common aspects for installation and equipment*.

Cables in tunnels, underground stops and underground traction substations shall be provided with low-smoke, low-toxicity and halogen-free oversheath.

Current ratings of cables shall be based upon the worst case maximum currents indicated in the traction power model with any necessary de-rating factors, such as those due to duct bank routing and ambient temperature.
All 750 V positive cables shall have a rated impulse voltage complying with EN 50124-1 Railway applications - Insulation coordination -- Part 1: Basic requirements - Clearances and creepage distances for all electrical and electronic equipment.

All 750 V positive cables shall have one of the following nominal conductor areas:

- 150 mm²
- 240 mm²
- 400 mm²

7. **Traction power reticulation cable containment**

The 750 V cable containment infrastructure shall comply with the requirements that are relevant to 1500 V dc cables in the following standards, with the exception of provisions set out in Section 7.1 and Section 7.2:

- T HR EL 20003 ST *Underground Installation Configurations for High Voltage and 1500 V dc Cables*
- EP 20 00 00 03 SP *Above Ground Cable Installation Systems - Selection Guide*
- EP 20 00 04 01 SP *Cable Route Selection Guide*
- EP 20 00 04 04 SP *Ground Entry Arrangements*
- EP 20 00 04 05 SP *Cable Pits*
- EP 20 00 04 06 SP *Underground Cable - Location Recording*

7.1. **Underground installation configurations**

T HR EL 20003 ST includes several requirements that are applicable only to installations within the heavy rail corridor. For light rail installations, these requirements are only applicable to areas within segregated routes with boundary fences installed along both sides of the alignment route.

It is permissible that ducts for 750 V positive and negative cables are encased within the concrete track slab, or in the concrete slab between the track slabs, at reduced depth.

For civil requirements that are applicable to undertrack crossings refer to T LR CI 12530 ST *Corridor Interface Requirements*.

7.2. **Above ground installation configurations**

Above ground installation configurations shall only be used in a cable installation that is located within high security environments.
Examples of permissible environments include the following:

- within traction substations
- cable pits
- cable tunnels and shafts
- within the secure confines of a depot

Above ground installation configurations shall not be used in areas that are accessible to the public, including the light rail corridor in separated or mixed routes.

Above ground installation configurations may be installed in areas within segregated routes with boundary fences installed along both sides of the alignment route, provided that the safety risk is controlled so far as is reasonably practicable (SFAIRP) in accordance with a risk analysis undertaken in the design process.

Ground line troughing (GLT) shall not be used.

7.3. **Traction power reticulation cables identification**

All cables shall be appropriately identifiable at each end and within cable pits.

8. **Lightning and surge protection**

Lightning and surge protection shall be provided to comply with the requirements of the following:

- T LR EL 00001 ST *Traction Power System Requirements*
- EN 50119 *Railway applications - Fixed installations - Electric traction overhead contact lines*
- EN 50124-1
- EN 50124-2 *Railway applications - Insulation coordination -- Part 2: Overvoltages and related protection*

9. **OLE**

The OLE shall be designed to meet the line speed at the relevant location.

Specific requirements for the OLE are set out Section 9.1 to Section 9.12. All other aspects of the OLE shall comply with the requirements of EN 50119 that are applicable to light rail systems.

The OLE system shall be designed to meet vehicle pantograph current requirements, including stationary loads, powering loads and loads under regenerative braking.
9.1. Contact wire horizontal displacement

The contact wire shall remain above the working zone of the pantograph head at maximum displacement of the contact wire from the superelevated centre-line so that the pantograph uplift is constrained by the contact wire under the worst cumulative effect of the following factors:

- **vehicle**
  - the pantograph dimensional characteristics as required by T LR EL 00007 ST Traction Power Supply Infrastructure and Light Rail Vehicle Interface
  - the working zone of the pantograph head - refer to Figure A.7 of EN 50367:2012 Railway applications - Current collection systems - Technical criteria for the interaction between pantograph and overhead line (to achieve free access) for an illustration of the working zone of the pantograph head
  - the vehicle dynamic parameters as required by T LR RS 00100 ST LRU 100 Series – Minimum Operating Standards for Light Rail Vehicles – General Interface Standards
  - pantograph position relative to bogie centre insofar as this creates end-throw or centre-throw

- **track**
  - the track geometry tolerances specified in T LR TR 10000 ST Light Rail Track Requirements, in particular the cross level tolerance and the track alignment tolerance

- **environment**
  - the design ranges of ambient conditions specified in EP 00 00 00 13 SP Electrical Power Equipment – Design Ranges of Ambient Conditions that are applicable to overhead wiring (OHW)

- **OLE**
  - the permissible range of contact wire heights specified in Section 9.6
  - deflection of OLE poles at the contact wire height due to wind
  - OLE erection tolerance
  - blow-off of contact wire due to wind
  - change in stagger due to swing of cantilevers

The allowable construction and maintenance tolerances of the relevant OLE design parameters shall be specified and documented in the design.
9.2. **Pantograph interface**

The OLE system shall comply with the pantograph interface requirements set out in T LR EL 00007 ST.

The contact wire alignment shall be arranged to provide, SFAIRP, an appropriate 'sweep' across the head of the pantograph to give an appropriate wear pattern without zones of significantly higher wear and without severe changes in the wear rate across the working zone of the pantograph.

9.3. **Converging contact wires**

Converging contact wires shall not contact the pantograph horn more than 60 mm below the top running surface of the pantograph.

Converging contact wires shall form the smallest practicable angle to the running track centre line at the point where the converging contact wire makes contact with the pantograph horn.

9.4. **Contact wire gradient**

The contact wire gradient is the ratio of the difference in height of the overhead contact line above the top of rail at two successive supports of the span and the span length.

The contact wire gradient shall not exceed the values set out in Table 1.

<table>
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<th>Speed (km/h)</th>
<th>Maximum contact wire gradient relative to track (%)</th>
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<tr>
<td>10</td>
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</tr>
<tr>
<td>20</td>
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<td>70</td>
<td>1.03</td>
</tr>
<tr>
<td>80</td>
<td>0.9</td>
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</tbody>
</table>

9.5. **Clearances to OLE**

The static and dynamic clearances to OLE equipment shall comply with EN 50119 with the exception that the minimum dynamic clearance shall be 70 mm.

The clearance between a pantograph and steady arms or any live parts connected to the contact wire shall not be less than 15 mm.
Clearances shall be achieved after the effects of track tolerances, wear and dynamic movement have been applied.

The design of the OLE shall take into account any existing aerial utility crossing and be in accordance with AS/NZS 7000 *Overhead line design*, allowing additional clearance as required for the safe undertaking of maintenance activities on the OLE.

### 9.6. Contact wire height

The nominal contact wire height in an open route shall be 5500 mm.

The contact wire height at the lowest point in any span in separated or mixed routes shall not be less than:

- 5.5 m for routes where 4.6 m high road vehicles are permitted
- 5.3 m for all other routes

The design contact wire height at supports shall take into consideration the following factors:

- effect of wire sag
- design conductor temperature range
- tension loss in conductors
- construction and maintenance tolerances of track and OLE equipment

The maintainer shall establish appropriate maintenance triggers and base safety and operating limits to control the risk due to the infringement of the minimum contact wire height requirement.

The contact wire height for in-running wire shall not be greater than 6100 mm above rail (consistent with the maximum pantograph current collection height of not less than 6200 mm above rail; see T LR EL 00007 ST).

The minimum contact wire height shall be suitable for the operation of a LRV with a height at the maximum outline dimensions specified in T LR RS 00100 ST.

### 9.7. OLE conductor tension

The tension in the contact wire shall comply with the permissible limits according to EN 50119.

The contact wire shall be auto-tensioned to maintain tension within 10% of nominal at all points along the contact wire.

The design range of movement of auto-tensioned conductors shall be consistent with ambient conditions specified in EP 00 00 00 13 SP that are applicable to OHW.
9.8. **Midpoint anchor**

Suitable anchor arrangements shall be used at or near the centre of each wire run with auto-tensioning devices installed at both ends to prevent along-track movement of the contact wire at that point.

9.9. **OLE in streetscapes**

A single contact wire for each track shall be used for OLE in streetscapes.

Any balance weight assemblies for auto-tensioning devices in streetscapes shall be installed within anchor poles.

9.10. **Helper cables**

Parallel underground helper cables may be provided to satisfy the following requirements:

- voltage drop
- fault loop resistance
- electromagnetic compatibility (EMC) at sensitive sites

Helper cables shall be connected to the OLE conductors at appropriate intervals to satisfy the helper cable requirements.

9.11. **OLE components**

All electrical connections to the in-running contact wire shall be made using high flexibility connections.

Insulating synthetic rope assemblies including the insulating synthetic rope and associated fittings shall be in accordance with EN 50345 *Railway applications - Fixed installations - Electric traction - Insulating synthetic rope assemblies for support of overhead contact lines*.

Loading of insulating synthetic rope assemblies shall be in accordance with the requirements of EN 50119.

9.12. **Protection from wildlife**

The OLE system shall be designed to minimise the risk to the OLE and wildlife in the event that wildlife comes into contact with the equipment.
10. **Protection against electric shock**

10.1. **Security and prevention of unauthorised access to OLE**

Protective provisions against direct contact shall be in accordance with EN 50122-1 *Railway applications - Fixed installations - Electrical safety, earthing and the return circuit - Part 1: Protective provisions against electric shock*.

To the greatest degree practicable, the clearance from places that might be accessed by persons to live OLE equipment shall be maximised.

Appropriate measures shall be taken to limit the access of persons to places not intended for public access and from which the safety clearances to live equipment might be infringed.

If safety clearances cannot be achieved by other means, safety screens shall be fitted at all locations where they are necessary to ensure personal safety and clearance limits to live equipment are achieved in accordance with EN 50122-1.

10.2. **Insulation**

The OLE system shall be a double insulated system in accordance with EN 61140.

Where practicable, the OLE insulators shall be separated so that one insulator is near the contact line and the other is near the OLE pole, in order to reduce the likelihood of persons or wildlife bridging both insulators.

The insulator near the contact line shall be positioned so as to minimise the 'live' envelope.

There shall be no live bare OLE equipment beyond the zone projected vertically from the running rails. Bare floating sections in this zone are acceptable.

10.3. **Sectioning switches**

Outdoor OLE sectioning switches within public access areas shall be adequately secured from unauthorised operation.

10.4. **Bonding of OLE poles**

OLE poles shall be bonded where required in accordance with T LR EL 00001 ST.

Additionally, OLE poles supporting unscreened 750 V feeder cables shall be bonded in accordance with the requirements of T LR EL 00001 ST in order to mitigate the risk of electric shock if an impact on the pole compromises the insulation of the cable.
11. **OLE poles**

11.1. **Civil and structural requirements**

The civil requirements for the design and construction of OLE poles are set out in T LR CI 12500 ST *Civil Infrastructure Design Standards*.

The civil requirements for the design and construction of OLE foundations are set out in T LR CI 12500 ST and T LR CI 12520 ST *Civil Infrastructure Construction*.

Loads on OLE poles and foundations due to OLE equipment shall be determined in accordance with EN 50119.

OLE poles and anchors shall be designed in accordance with AS/NZS 1170 (all parts) *Structural design actions*.

OLE piles shall be designed and installed in accordance with AS 2159 *Piling – Design and installation*.

OLE poles shall be designed in accordance with AS 4100 *Steel structures*.

OLE poles shall be hot-dip galvanised in accordance with AS/NZS 4680 *Hot-dip galvanized (zinc) coatings on fabricated ferrous articles*.

The maximum deflection of OLE poles at the contact wire height due to dynamic loading shall be consistent with Section 9.1.

In order to produce an acceptable aesthetic appearance, OLE pole deflection under static serviceability loading (permanent actions only, no imposed or wind actions) shall not cause the OLE pole to lean towards the load. Beneficial pre-set rake may be provided to satisfy this requirement.

The design of OLE poles shall address potential overload contingencies such as wire breakage and vehicle impact as follows:

- Reduce the risk of vehicle impacts by careful placement of poles.
- Design the pole to bend progressively if overloaded rather than tearing or breaking – this will minimise the risk of the OLE actually being brought down.
- For the design of pole anchor bolts, pole bases and structural aspects of foundations, the load factor shall be taken as 1.75 for the ultimate limit state and 1.30 for any serviceability limit state. The purpose of the enhanced load factors is to ensure that in the event of an overload due to collision or wire breakage, the items described should be in an undamaged state and only the OLE structure section may need replacement. The design of such items shall include the effects of any corrosion.
11.2. **Location of OLE poles**

The location of OLE poles shall satisfy the following criteria:

- the number of poles is minimised
- the visual impact of the OLE system is reduced
- the collision risk for both LRVs and road vehicles (including the collision with a road vehicle after the road vehicle has been struck by a LRV) is minimised
- the OLE performance criteria (including the criteria for maximum span lengths and maximum mid-span offset)

11.3. **OLE pole identification**

OLE poles shall be identified with a unique identifier label. The identifier shall include an element that is based on chainage.

11.4. **Attachments to OLE poles**

Attachments to OLE poles shall be consistent with pole capacity, in particular the mode and location of application of point loads.

11.5. **Lightning protection of OLE poles**

Lightning protection of OLE poles shall be considered, especially at high-risk locations such as stops where the requirements of AS/NZS 1768 *Lightning protection* shall be considered.

11.6. **Shared poles**

Shared (multi-function) poles shall be used wherever possible in order to reduce the number of poles in the streetscape.

- On any shared OLE poles, the system shall be configured so that no fault can result in 750 V dc flowing in the protective earth conductor or any joint-use system mounted on OLE poles.
- On any shared lighting and OLE poles, the lighting equipment shall be electrically insulated from the traction power system and separately bonded to earth in accordance with EN 50122-1.

11.7. **Aesthetics**

OLE poles in street or plaza environments shall be designed to minimise visual clutter. Fixings, splices, insulated couplings and so on shall be concealed where practicable. Colour and finish shall be consistent with the urban design objectives applicable to the location.
Nominated multi-functional poles shall be used as far as practicable where stipulated by the local authority.

11.8. **Graffiti resistance**

At least 3 m of the lower portion of OLE poles shall be resistant to graffiti. Where a specific aesthetic outcome is required any anti-graffiti coating shall not adversely affect the colour and appearance of the pole.

11.9. **Protrusions**

OLE poles in pedestrian areas shall have no protrusions at the pavement surface such as visible base-plates, holding down bolts, plinths and so forth.

11.10. **Durability**

All buried steelwork including base plates, shall be suitably protected to ensure that the design life requirements for OLE poles as specified in T LR C1 12500 ST are met. Examples of suitable protection include the provision of additional paint coating and concrete encasement.

12. **Aesthetic power system**

The aesthetic power system (APS) is an Alstom proprietary segmented third rail system requiring two collector shoes under each LRV.

The interface between fixed infrastructure and the LRV is set out in Alstom’s SLR ALS D50 RST SPE 000156 *Sydney Light Rail- Interface Specification Rolling Stock / Power Supply*.

The power rail segments shall only be energised when fully under the LRV.

Enclosure of any APS equipment shall have a degree of ingress protection (IP) rating consistent with the design environmental conditions, particularly those relating to rainfall and flooding.

If APS is used then the drainage design shall be coordinated with the allowable depth of water for satisfactory APS operation.

13. **Ground contact charging system infrastructure**

To support wire-free operation, LRVs may be equipped with onboard energy storage that can be charged at the ground-level by shoe contacts at light rail stops and other charging locations.

Any ground contact charging system shall be in accordance with the supplier’s specifications.

The power rail segments shall only be energised when fully under the LRV.
Any ground contact charging system equipment shall have an IP rating consistent with the design environmental conditions, particularly those relating to rainfall and flooding.

14. **Overhead contact charging system infrastructure**

To support wire-free operation, LRVs may be equipped with onboard energy storage that can be charged by pantograph contact with short sections of overhead line or a rigid contact bar provided at light rail stops and other charging locations.

The length of any overhead contact charging conductor shall be sufficient to coordinate with the pantograph positions and tolerance at the charging point.

An overhead contact charging conductor may be either energised continuously or energised only when there is an LRV present. The chosen energisation strategy shall be taken into account in the risk assessment process. If an overhead contact charging conductor is to be energised only when there is an LRV present then the energisation state of the overhead contact charging conductor shall be monitored and an alarm indicated at the operation control centre (OCC) if the conductor is energised with no LRV present.

The height of any overhead charging conductor that is energised continuously shall not be less than the minimum contact wire height specified in Section 9.6.

If an overhead contact charging conductor is to be energised only when there is an LRV present then the height of any overhead contact charging conductor shall be not less than 4.5 m above rail and shall be higher consistent with any possible road vehicle movements through the stop or charging point.

15. **Traction return**

The arrangement of traction return connections to the running rails shall be such that traction current does not interfere with the proper operation of any LRV movement control system.

Cross bonds between rails and between tracks shall be provided at appropriate intervals to limit rail to earth voltage.

In the case of embedded track, cross bonds shall be arranged so that if the re-connection to the rail is required, it will not be necessary to expose the connection to another rail at the other end of the bond cable and replace the bond cable end-to-end. One example of a cross bond arrangement is described in Appendix A. Other arrangements are acceptable provided they are in accordance with Section 15.
Appendix A  Cross bond arrangement

Figure 1 shows an arrangement of cross bonds that would facilitate a reconnection to rail. The drawing is informative only and should be used as a reference.

![Diagram of cross bond arrangement](image)

**Figure 1**– Arrangement of cross bonds to facilitate re-making a connection to rail

If a single rail is replaced, then the cross bond cable may be spliced with a suitable compression crimp in the pit. Insulation should be reinstated with heat-shrink.

To make an external connection for a stray current test point or mitigation, one or more of the cross-bond cables may be cut and terminated on a suitable busbar (or similar) to which the external connection may be made.

If a voltage-limiting device (VLD) is required in the vicinity of the cross-bond, then the VLD should be connected to the cross bond rather than making a separate connection to the rail.