



**TS 03785:1.0**  
T LR EL 00005 ST  
**Standard**

# **Direct Current Traction Power Reticulation for Light Rail**

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1.0	25 May 2017	First issue as T LR EL 00005 ST.
2.0	24 May 2018	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.
1.0	04 September 2025	First issue as TS 03785, superseding T LR EL 00005 ST, version numbering recommenced in line with new designation. Changes from the previous version include clarifications to contact wire height and details pertaining to ground level power supply systems.

## Preface

This standard is a first issue as TS 03785, superseding T LR EL 00005 ST *Direct Current Traction Power Reticulation* version 2.0.

This document 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 LRVs of a light rail system.

Changes from the previous version include clarifications to contact wire height and details pertaining to ground level power supply systems.

## Table of contents

<b>1</b>	<b>Scope</b> .....	<b>7</b>
<b>2</b>	<b>Application</b> .....	<b>7</b>
<b>3</b>	<b>Referenced documents</b> .....	<b>7</b>
<b>4</b>	<b>Terms, definitions and abbreviations</b> .....	<b>9</b>
<b>5</b>	<b>Traction power reticulation sectioning and connectivity</b> .....	<b>10</b>
5.1	Sectioning .....	10
5.2	Open overlaps.....	10
5.3	Insulated rail joints.....	10
5.4	Arrangements for double-track sections.....	10
5.5	Stabling areas .....	11
5.6	Maintenance areas.....	11
<b>6</b>	<b>Traction power reticulation cables specification</b> .....	<b>11</b>
<b>7</b>	<b>Traction power reticulation cable containment</b> .....	<b>12</b>
7.1	General requirements.....	12
7.2	Underground installation configurations .....	12
7.3	Above ground installation configurations.....	12
7.4	Traction power reticulation cables identification .....	13
<b>8</b>	<b>Lightning and surge protection</b> .....	<b>13</b>
<b>9</b>	<b>Overhead line equipment</b> .....	<b>13</b>
9.1	General requirements.....	13
9.2	Contact wire horizontal displacement.....	13
9.3	Pantograph interface .....	14
9.4	Converging contact wires .....	15
9.5	Contact wire gradient.....	15
9.6	Clearances to overhead line equipment.....	15
9.7	Contact wire height.....	15
9.8	Overhead line equipment conductor tension .....	16
9.9	Midpoint anchor.....	16
9.10	Overhead line equipment in streetscapes .....	16
9.11	Helper cables .....	17
9.12	Overhead line equipment components.....	17
9.13	Protection from wildlife.....	17
<b>10</b>	<b>Protection against electric shock</b> .....	<b>17</b>
10.1	Security and prevention of unauthorised access to overhead line equipment .....	17
10.2	Insulation.....	18
10.3	Sectioning switches.....	18
10.4	Bonding of overhead line equipment poles.....	18
<b>11</b>	<b>Overhead line equipment poles</b> .....	<b>18</b>
11.1	Civil and structural requirements.....	18

- 11.2 Location of overhead line equipment poles ..... 19
- 11.3 Overhead line equipment pole identification ..... 19
- 11.4 Attachments to overhead line equipment poles ..... 19
- 11.5 Lightning protection of overhead line equipment poles ..... 20
- 11.6 Shared poles ..... 20
- 11.7 Aesthetics ..... 20
- 11.8 Graffiti resistance ..... 20
- 11.9 Protrusions ..... 20
- 11.10 Durability ..... 20
- 12 Ground level power supply system ..... 21**
- 13 Ground contact charging system infrastructure ..... 21**
- 14 Overhead contact charging system infrastructure ..... 21**
- 15 Traction return ..... 22**
- Appendix A Cross bond arrangement ..... 23**

# 1 Scope

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

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

# 2 Application

This document is applicable to all new light rail dc traction power reticulation systems.

This document is also applicable to the modification of existing light rail 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 document are applicable to the configuration at each stage of construction.

Unless otherwise stated, application is not retrospective to existing infrastructure that is not otherwise being altered.

This document 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 document, asset decisions take into account the life cycle cost considerations specified in TS 01505.

# 3 Referenced 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 *Fixed installations for railway applications – 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 *Railway applications – Fixed installations and rolling stock – Criteria to achieve technical compatibility between pantographs and overhead contact line*

IEC 61140 *Protection against electric shock – Common aspects for installation and equipment*

**Australian standards**

AS 1768 *Lightning protection*

AS 2159 *Piling – Design and installation*

AS 4100 *Steel structures*

AS/NZS 1170 *Structural design actions (all parts)*

AS/NZS 4680 *Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods*

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**

TS 01505 (T MU AM 01001 ST) *Life Cycle Costing*

TS 01647 (T LR CI 12500 ST) *Civil Infrastructure Design Standards*

TS 01648 (T LR CI 12520 ST) *Civil Infrastructure Construction*

TS 02361 (T LR CI 12530 ST) *Corridor Interface Requirements*

TS 03552 (T LR TR 10000 ST) *Light Rail Track Requirements*

TS 03744 (EP 00 00 00 13 SP) *Electrical Power Equipment – Design Ranges of Ambient Conditions*

TS 03750 (T HR EL 20003 ST) *Underground Installation Configurations for High Voltage and 1500 V dc Cables*

TS 03751 *High Voltage AC and 1500 V DC Traction Power Supply Cable Infrastructure – Standards for Design and Construction*

TS 03752 *Guide to Above Ground Installation Configurations for High Voltage AC and 1500 V DC Cables*

TS 03753 (T HR EL 20006 ST) *High Voltage ac and 1500 V dc Cables – Transitions Between Underground and Above Ground Installation Configurations*

TS 03754 (T HR EL 20007 ST) *Cable Pits*

TS 03755 (T HR EL 20008 ST) *Underground Cables and Cable Enclosures – Location Data Recording*

TS 03786 *Traction Power Supply Infrastructure and Light Rail Vehicle Interface*

TS 03789 (T LR EL 00001 ST) *Traction Power System Requirements*

TS 04079.2 (T LR RS 00100 ST) *LRU 100 Series – Minimum Operating Standards for Light Rail Vehicles – General Interface Standards*

TS 03773 *Requirements for Electric Aerials Crossing Transport for NSW Heavy Rail Infrastructure*

## 4 Terms, definitions and abbreviations

The following terms, definitions and abbreviations apply in this document.

**alignment route** the corridor or path of the light rail

**dc** direct current

**DCCB** direct current circuit breaker

**EMC** electromagnetic compatibility

**EPR** ethylene propylene rubber

**GLT** ground line troughing

**IP** ingress protection rating

**LRV** light rail vehicle

**mixed route** fully integrated into the road space used by light rail, road users and pedestrians

**OHW** overhead wiring

**OLE** overhead line equipment

**open route** track alignment not covered by an overbridge or within a tunnel

**segregated route** a dedicated fenced corridor for light rail use only to which access for other road and rail traffic, and pedestrians is controlled

**separated route** intended for exclusive use by light rail but integrated into the road space in such a way that occasional access by other traffic and pedestrians is possible

**SFAIRP** so far as is reasonably practicable

**VLD** voltage-limiting device, a protective device whose function is to prevent existence of an impermissible high voltage

**XLPE** cross-linked polyethylene

## **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 an 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, the 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 unearthed 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 an 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 separately switchable section from the stabling areas and should preferably be fed from a separate 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.

Cables shall also have the following characteristics:

- conductor – stranded copper
- polymeric oversheath providing adequate protection against mechanical damage for the designed construction method and site environment
- insulation – XLPE or EPR.

TAO shall determine whether a metallic screen is required for positive cables.

However, reduced fire hazard cable material suitable for up to a 90 degree Celsius continuous operating temperature, in accordance with AS/NZS 5000.1, is to be used for cables in tunnels, underground stops and underground substations.

All 750 V positive cables shall have double insulation complying with class II equipment, in accordance with IEC 61140.

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 derating 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.

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

- 150 mm<sup>2</sup>
- 240 mm<sup>2</sup>
- 400 mm<sup>2</sup>.

TAO shall determine the characteristics of negative cables to be used in the system.

## **7 Traction power reticulation cable containment**

### **7.1 General requirements**

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 7.2 and Section 7.3:

- TS 03750
- TS 03751
- TS 03752
- TS 03753
- TS 03754
- TS 03755.

### **7.2 Underground installation configurations**

TS 03750 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.

Ducts for 750 V positive and negative cables may be 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 TS 02361.

### **7.3 Above ground installation configurations**

Above ground installation configurations shall only be used in cable installations located within high-security environments.

Examples of acceptable high security 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, SFAIRP, in accordance with a risk analysis undertaken in the design process.

GLT shall not be used.

## 7.4 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:

- TS 03789
- EN 50119
- EN 50124-1
- EN 50124-2.

# 9 Overhead line equipment

## 9.1 General requirements

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

Specific requirements for OLE are set out in Section 9.2 to Section 9.13. All other aspects of 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. The components used for OLE are to be assessed by that TAO for type approval on basis of criticality to the operation of light rail systems.

## 9.2 Contact wire horizontal displacement

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 specified in TS 03786
  - the vehicle dynamic parameters, as specified in TS 04079.2
  - pantograph position relative to bogie centre, insofar as this creates end-throw or centre-throw

Note: refer to Figures A.6 and A.7 of EN 50367 for illustrations of the working zone of the pantograph head

- track
  - the track geometry tolerances specified in TS 03552, in particular the cross-level tolerance and the track alignment tolerance
- environment
  - the design ranges of ambient conditions specified in TS 03744 that are applicable to OHW
- OLE
  - the permissible range of contact wire heights specified in Section 9.7
  - deflection of OLE poles at the contact wire height due to wind
  - OLE erection tolerance
  - blowout 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.

### 9.3 Pantograph interface

The OLE system shall comply with the pantograph interface requirements set out in TS 03786.

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.

## 9.4 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.

## 9.5 Contact wire gradient

The contact wire gradient is the ratio of the difference in height of the overhead contact line above the top of the 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 1 – Maximum contact wire gradient**

Speed (km/h)	Maximum contact wire gradient relative to track (%)
10	3.6
20	3.6
30	2.4
40	1.8
50	1.44
60	1.2
70	1.03
80	0.9

## 9.6 Clearances to overhead line equipment

Static and dynamic clearances to OLE shall comply with EN 50119, with the exception that the minimum dynamic clearance shall be 70 mm.

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 and TfNSW standard TS 03773, allowing additional clearance as required for the safe undertaking of maintenance activities on the OLE.

## 9.7 Contact wire height

The nominal contact wire height in an open route shall be 5.5 m.

The contact wire height at the lowest point in any span in 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, base safety and operating limits to control the risk due to infringement of the minimum contact wire height requirement.

The contact wire height for in-running wire shall not be greater than 6.1 m above rail, consistent with the maximum pantograph current collection height of not less than 6.2 m above rail. For more information, refer to TS 03786.

The minimum contact wire height shall be suitable for the operation of an LRV with a height at the maximum outline dimensions specified in TS 04079.2.

## 9.8 Overhead line equipment conductor tension

The tension in the contact wire shall comply with the limits specified in EN 50119.

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

The design range of movement of auto-tensioned conductors shall be consistent with ambient conditions specified in TS 03744 that are applicable to OHW.

## 9.9 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.

## 9.10 Overhead line equipment in streetscapes

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

Any balance weight assemblies for auto-tensioning devices or spring tensioners in streetscapes shall be installed on anchor poles.

## 9.11 Helper cables

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

- voltage drop
- fault loop resistance
- EMC at sensitive sites.

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

## 9.12 Overhead line equipment 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.

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

## 9.13 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 overhead line equipment

Protective provisions against direct contact shall be in accordance with EN 50122-1.

To the greatest degree practicable, the clearance from places that might be accessed by persons to live OLE 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 can 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 beyond the zone projected vertically from the running rails. Bare floating sections in this zone may be used.

## 10.3 Sectioning switches

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

## 10.4 Bonding of overhead line equipment poles

OLE poles shall be bonded where required in accordance with TS 03789.

Additionally, OLE poles supporting unscreened 750 V feeder cables shall be bonded in accordance with the requirements of TS 03789, in order to mitigate the risk of electric shock if an impact on the pole compromises the insulation of the cable.

# 11 Overhead line equipment poles

## 11.1 Civil and structural requirements

The civil requirements for the design and construction of OLE poles are set out in TS 01647.

The civil requirements for the design and construction of OLE foundations are set out in TS 01647 and TS 01648.

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

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

OLE piles shall be designed and installed in accordance with AS 2159.

OLE poles shall be designed in accordance with AS 4100.

OLE poles shall be hot-dip galvanised in accordance with AS/NZS 4680.

The maximum deflection of OLE poles at the contact wire height due to dynamic loading shall be consistent with Section 9.2.

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 preset rake may be provided to satisfy this requirement. Site survey during construction is preferred to insure proper rake implementation.

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

- reducing the risk of vehicle impacts by careful placement of poles
- designing the poles to bend progressively if overloaded, rather than tearing or breaking, minimising the risk of the OLE 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 is to take into consideration the effects of any corrosion.

## 11.2 Location of overhead line equipment 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 OLE performance criteria (including the criteria for maximum span lengths and maximum mid-span offset)
- the collision risk for both LRVs and road vehicles (including collision with a road vehicle after the road vehicle has been struck by an LRV) is minimised.

## 11.3 Overhead line equipment 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 overhead line equipment 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 overhead line equipment poles

Lightning protection of OLE poles shall be taken into consideration, especially at high-risk locations, such as stops, where the requirements of AS 1768 are to be taken into consideration.

## 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 TS 01647, are met. Examples of suitable protection include the provision of additional paint coating and concrete encasement.

## 12 Ground level power supply system

Ground level power supply system is a segmented third rail system requiring two collector shoes under each LRV. The power rail segments shall only be energised when fully under the LRV.

## 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 consideration in the risk assessment process. If an overhead contact charging conductor is to be energised only when there is an LRV present, the energisation state of the overhead contact charging conductor shall be monitored, and an alarm indicated at the operation control centre if the conductor is energised with no LRV present.

The height of any overhead charging conductor energised continuously shall not be less than the minimum contact wire height specified in Section 9.7.

If an overhead contact charging conductor is to be energised only when there is an LRV present, the height of any overhead contact charging conductor shall be not less than 5.5 m above rail and maximum vehicle height allowed access is 4.6 m. The height of any overhead contact charging conductor shall be higher consistent with any possible road vehicle movements through the stop or charging point.

## 15 Traction return

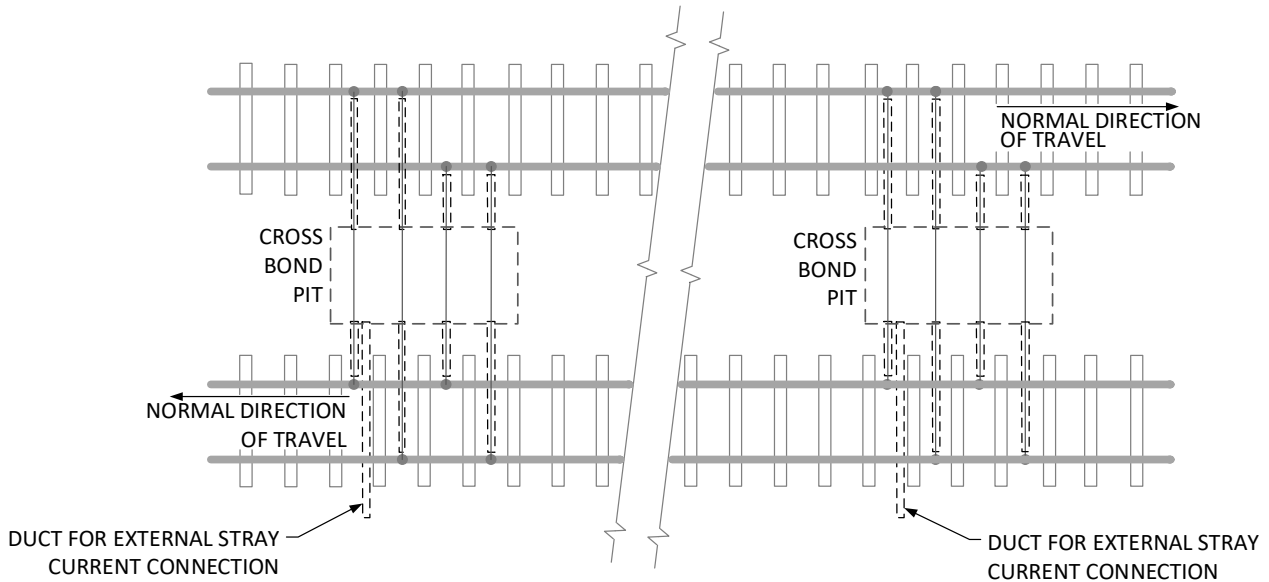
The arrangement of traction return connections to the running rails shall be such that traction current does not interfere with the proper operation of any LRV movement control system.

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 reconnection to the rail is required, it is not 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 may be used provided they are in accordance with this Section.

## Appendix A Cross bond arrangement

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



**Figure 1 – Arrangement of a cross bond to facilitate remarking 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 VLD is required in the vicinity of the cross bond, the VLD should be connected to the cross bond rather than making a separate connection to the rail.