Electrical Circuits and Equipment for Light Rail Vehicles

Version 2.0
Issued date: 07 November 2017
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Standard governance

Owner: Lead Rolling Stock Engineer, Asset Standards Authority  
Authoriser: Chief Engineer, Asset Standards Authority  
Approver: Executive Director, Asset Standards Authority on behalf of the ASA Configuration Control Board

Document history

<table>
<thead>
<tr>
<th>Version</th>
<th>Summary of changes</th>
</tr>
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<tbody>
<tr>
<td>1.0</td>
<td>First issued 25 May 2017</td>
</tr>
<tr>
<td>2.0</td>
<td>Updates of general requirements. Removal of requirements for the onboard main power supply.</td>
</tr>
</tbody>
</table>

For queries regarding this document, please email the ASA at standards@transport.nsw.gov.au or visit www.asa.transport.nsw.gov.au
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

The ASA has issued this document to state the minimum requirements for the design, manufacture and supply of new and significantly modified light rail passenger vehicles for TfNSW.

This standard has been prepared by the ASA in consultation with other TfNSW agencies and light rail vehicles’ designers, manufacturers, suppliers and contractors.

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

- general update of the requirements
- requirements for the onboard main power supply have been moved to a new standard, T LR RS 11001 ST Onboard Main Power and Auxiliary Power Supply Systems for Light Rail Vehicles
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1. Introduction

The performance and safety of electrical systems on Transport for NSW (TfNSW) light rail passenger vehicles is paramount to TfNSW public transport operations. This standard enables TfNSW to ensure the light rail vehicles (LRVs) used in their operations meet the minimum requirements for performance and safety.

2. Purpose

This document provides the minimum requirements and recommendations for electrical circuits and electrical equipment used on TfNSW LRVs. This standard aims to ensure the reliability, availability, maintainability and safety of electrical circuits and equipment in new and refurbished TfNSW LRVs.

2.1. Scope

This standard covers requirements for electrical circuits and electrical equipment in the following light rail rolling stock systems:

- traction systems
- power supply systems
- auxiliary systems
- communication and control systems

2.2. Application

This standard applies to the procurement of new light rail passenger vehicles for TfNSW.

This standard also applies to existing light rail passenger vehicles that are to undergo substantial modification.

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 50121-1 Railway Applications - Electromagnetic Compatibility - Part 1: General

EN 50121-3-1 Railway Applications - Electromagnetic Compatibility - Part 3-1: Rolling Stock - Train and Complete Vehicle
EN 50121-3-2 Railway Applications - Electromagnetic Compatibility - Part 3-2: Rolling Stock – Apparatus

EN 50153 Railway Applications – Rolling Stock – Protective Provisions Relating to Electrical Hazards

EN 50155 Railway Applications - Electronic Equipment Used on Rolling Stock

EN 50343 Railway Applications – Rolling Stock – Rules for Installation of Cabling

IEC 60034-1 Rotating electrical machines – Part 1: Rating and performance

IEC 60051-1 Direct acting indicating analogue electrical measuring instruments and their accessories - Part 1: Definitions and general requirements common to all parts

IEC 60077 (series) Railway Applications – Electric equipment for rolling stock

IEC 60349-1 Electric traction - Rotating electrical machines for rail and road vehicles - Part 1: Machines other than electronic converter-fed alternating current motors

IEC 60349-2 Electric traction - Rotating electrical machines for rail and road vehicles - Part 2: Electronic converter-fed alternating current motors

IEC 60349-4 Electric traction - Rotating electrical machines for rail and road vehicles - Part 4: Permanent magnet synchronous electrical machines connected to an electronic converter

IEC 61373 Railway applications - Rolling stock equipment - Shock and vibration tests

**Australian standards**

AS 60038-2012 Standard Voltages

AS/NZS 3112 Approval and test specification - Plugs and socket-outlets

**Transport for NSW standards**

T LR EL 00007 ST Traction Power Supply Infrastructure and Light Rail Vehicle Interface

T LR RS 01701 ST Mounting and Installation of Electrical Equipment for Light Rail Vehicles

T LR RS 11001 ST Onboard Main Power and Auxiliary Power Supply Systems for Light Rail Vehicles

T LR RS 17010 ST Light Rail Vehicle Fire Safety

T MU AM 01003 ST Development of Technical Maintenance Plans

T MU RS 00164 ST Cables for Passenger Rolling Stock

T MU RS 17001 ST Environmental Conditions for Rolling Stock

T MU RS 17002 ST Prohibited and Restricted Materials
4. **Terms and definitions**

The following terms and definitions apply in this document:

- **ac** alternating current
- **ASA** Asset Standards Authority
- **dc** direct current
- **HSCB** high-speed circuit breaker
- **LRV** light rail vehicle
- **TfNSW** Transport for NSW
- **vehicle body** (in the context of this document) refers to the body of individual LRV vehicle modules

5. **General requirements**

All passenger rolling stock electrical circuits and equipment shall comply with the relevant sections of the following standards:

- EN 50153 *Railway Applications – Rolling Stock – Protective Provisions Relating to Electrical Hazards*
- EN 50155 *Railway Applications – Electronic Equipment Used on Rolling Stock*
- EN 50343 *Rolling Stock – Rules for Installation of Cables*
- IEC 60077-1 *Railway Applications – Electric equipment for rolling stock – Part 1: General Service conditions and general rules*
- IEC 60034-1 *Rotating electrical machines – Part 1: Rating and performance*
- T LR RS 01701 ST *Mounting and Installation of Electrical Equipment for Light Rail Vehicles*

5.1. **Electromagnetic compatibility**

Light rail vehicle (LRV) electrical circuits and equipment shall not have an impact on the operation of other onboard electrical systems.

LRV electrical circuits and equipment shall not have an impact on the operation of light rail and road electrical infrastructure such as signalling systems.
The LRV shall comply with and be tested for electromagnetic compatibility in accordance with the following standards:

- EN 50121-1 *Railway Applications - Electromagnetic Compatibility - Part 1: General*
- EN 50121-3-1 *Railway Applications - Electromagnetic Compatibility - Part 3-1: Rolling Stock - Train and Complete Vehicle*
- EN 50121-3-2 *Railway Applications - Electromagnetic Compatibility - Part 3-2: Rolling Stock – Apparatus*

### 5.2. Prohibited materials requirements

Materials used in rolling stock electrical circuitry and electrical equipment shall comply with the requirements of T MU RS 17002 ST *Prohibited and Restricted Materials.*

### 5.3. Fire performance requirements

Materials used in LRV electrical circuitry and electrical equipment shall comply at a minimum with the fire performance requirements of T LR RS 17010 ST *Light Rail Vehicle Fire Safety.*

Electrical cable fire performance requirements shall at a minimum comply with T MU RS 00164 ST *Electrical Cable for Passenger Rolling Stock.*

### 5.4. Operating environment

The maximum and minimum ambient operating temperature ranges, humidity levels, precipitation levels and other environmental operating conditions in NSW shall be used in the selection and design of vehicle electrical systems and equipment to ensure the specified reliability and life span.

For the purpose of design calculations and applying referenced standards, the operating temperatures and environmental conditions shall be derived using the environmental conditions as defined in T MU RS 17001 ST *Environmental Conditions for Rolling Stock.*

### 5.5. Circuit diagrams drawings

Circuit diagram drawings shall be provided for all vehicle electrical circuits to enable maintenance and future alterations.

Drawings shall be provided for the following:

- legends of all component symbols
- abbreviation tables
- zone index of numbered circuit links, wires and circuit components
Graphical symbols in circuit diagrams shall comply with EN 60617 or an equivalent standard.

5.6. Technical manuals

All vehicle electrical circuits and electrical equipment shall be provided with a detailed technical manual.

The technical manual shall include relevant safety warnings against risks and hazards while operating or maintaining all electrical circuit and equipment.

The technical manual shall use, where applicable, functional systems diagrams, sequence charts and other diagrams necessary to explain the operation of circuits and electrical equipment to electrical technicians and engineers to enable detailed assessment, maintenance, fault-finding and future modification and upgrades to the rolling stock electrical system.

Technical manuals shall be included for plug-in type modules, including plug-in circuit board cards contained within larger equipment modules which may not be readily accessible.

Explanation of relevant circuit theory may also be included to completely describe the operation of electrical circuits.

The technical manuals shall include detailed installation and overhaul instructions for all electrical equipment, including the tools and equipment required to efficiently complete the task.

The technical manuals shall include a comprehensive diagnostics and fault-finding procedure, including test sequence and expected measurable values such as voltage, resistance and current readings.

Technical manuals shall also be included for bespoke test equipment used to test electrical equipment.

5.7. Technical maintenance plans

The technical maintenance plan shall detail all the maintenance requirements to enable the electrical circuit and equipment to operate as specified and to prevent in-service failures.

The technical maintenance plan shall detail all the maintenance requirements to ensure the specified life of the electrical circuit and equipment.

Technical maintenance plans shall be provided for all LRV electrical circuits and equipment.

The technical maintenance plan shall comply with T MU AM 01003 ST Development of Technical Maintenance Plans.
5.8. **General circuit voltages**

Vehicle control and lighting circuits shall not exceed extra low voltage (EN 50153).

Vehicle single phase ac circuit voltages and frequency shall be nominal 230 V ac, 50 Hz for auxiliary systems and general power outlets, in accordance with AS 60038-2012 *Standard Voltages*.

General power outlets shall comply with AS/NZS 3112 *Approval and test specification - Plugs and socket-outlets*.

Vehicle three phase ac circuit voltages and frequency shall be nominal 400 V ac, 50 Hz in accordance with AS 60038-2012.

The traction supply voltage on TfNSW light rail networks is nominal 750 V dc in accordance with T LR EL 00007 ST *Traction Power Supply Infrastructure and Light Rail Vehicle Interface*.

The minimum electrical creepage distance between parts energised at the potential of the infrastructure power supply and any part of the vehicle body shall be determined in accordance with EN 60077-1 *Railway Applications – Electric Equipment for Rolling Stock – Part 1: General Service Conditions and General Rules*.

For voltages over 1000 V, creepage distance shall not be less than 45 mm/kV.

6. **Electrical protection and safety**

LRV electrical safety provisions shall comply with EN 50153.

LRVs shall be provided with the following electrical protection and safety systems:

- safety earthing switch or equivalent system
- onboard power source overcurrent protection
- individual circuit (functions) overcurrent protection and isolation device

6.1. **Safety earthing switch (disconnect and earth)**

A safety earthing switch or equivalent system shall be provided to enable maintenance personnel to positively disconnect and earth the LRV’s main power supply circuit and secure it to provide protection from inadvertent application of power from any source.

Safety earthing switch requirements are detailed in T LR RS 11001 ST *Onboard Main Power and Auxiliary Power Supply Systems for Light Rail Vehicles*.
6.2. **Power source protection**

All onboard power sources including auxiliary inverters, auxiliary batteries and onboard traction power storage systems shall be protected by magnetic circuit breakers and high rupturing capacity (HRC) fuses where applicable.

The performance and reaction time of individual circuit breakers in-circuit shall be verified by simulation or testing to ensure it is able to provide the required protection under the worst-case conditions.

Auxiliary and traction battery banks shall be protected by HRC fuses or equivalent fuses on both the positive and negative terminals.

All onboard power sources including auxiliary inverters, auxiliary batteries and onboard traction power storage systems shall be provided with a method of isolation that can be protected using a LOTO procedure. LOTO refers to 'lockout-tagout' and is a safety procedure used in industry to ensure that dangerous machines are properly shut off and not started up again prior to the completion of maintenance or servicing work.

Three-phase ac power load shall be balanced to ensure that load at each phase remain within +/-5% of each other under normal operating conditions.

Traction dc buses shall be protected by an insulation monitoring device (IMD) or equivalent to protect against ground faults due to insulation break down or failure.

6.3. **Protection and isolation of individual circuit functions**

Individual circuit functions and equipment shall be protected using overcurrent magnetic circuit breakers that can be used to isolate the individual circuit functions.

The selection of circuit breakers shall take into account circuit characteristics, including the effects of long cable runs, to ensure the desired reaction time of the circuit breaker.

The performance and reaction time of individual circuit breakers in-circuit shall be verified by simulation or testing to ensure it is able to provide the required protection under worst-case conditions.

Three-phase ac power sources and circuits shall be protected by ganged three phase magnetic circuit breakers.

Circuit breakers shall not be used in lieu of dedicated switches or switch controlled contactors where regular manual hand switching is required for an electrical circuit or equipment.
7. **Onboard main and auxiliary power supply systems**

The following onboard main power supply and auxiliary power supply systems and equipment are covered in T LR RS 11001 ST *Onboard Main Power and Auxiliary Power Supply Systems Light Rail Vehicle*:

- traction supply current return arrangement
- wheel axle earthing unit – wheel axle earthing units are used for equipotential bonding of the vehicle body to the running rails and for the main power supply current return to the running rails
- auxiliary power supply system – converts the main power supply voltage for the auxiliary systems
- auxiliary power supply battery systems – provides emergency back-up power for operational and safety critical systems
- traction power battery systems – provides power to the traction system for wire free operations and may be used to capture regenerative braking energy for traction use

8. **Earthing system**

The earthing arrangements shall provide robust protective and functional earthing.

Protective earthing shall be provided in the form of equipotential earth bonding of all exposed or accessible conductive components, enclosures and panels to prevent electric shocks and to enable the operation of overcurrent protection devices in the event of inadvertent energisation due to credible failure modes.

Functional earthing shall be provided to prevent the flow of current (from all sources) through the vehicle body and bogie components including uninsulated bearings.

Functional earthing shall prevent interference by preventing the induction of stray current and signals to other onboard systems.

All vehicle electrical circuits shall comply with the protective earthing requirements in EN 50153.

8.1. **Vehicle body earthing system**

The vehicle body earthing system shall electrically bond the vehicle and bogie structures to the running rails using multiple wheel axle earthing units.

The vehicle body earthing system shall prevent dangerous voltages from developing between the running rails and the LRV.
The vehicle body earthing circuit shall use a minimum of two separate redundant paths to the running rails using a minimum of two separate wheel axle earthing units on separate bogies.

The use of multiple paths through wheel axle earthing units located on multiple bogies enables the earthing bond to be maintained during a derailment of one of the bogies.

The vehicle body earthing circuit paths shall go directly to the wheel axle earthing units with no intermediate electrical connections to the bogies.

The vehicle body earthing system shall effectively conduct fault currents to the vehicle body to the running rails, in the event of failed overhead power supply cables or equipment making contact with the vehicle body, to enable the immediate tripping of the substation's high-speed circuit breakers (HSCBs).

The main power supply current return circuits shall be isolated from the vehicle body earthing circuit up to the wheel axles.

Failure of the wheel axle earthing units shall not cause the main power supply current return to energise the vehicle body earthing circuit.

The vehicle body earthing system shall ensure no electrical currents, including currents from the running rails, flow through any non-insulated bearings including the wheel axle bearings.

### 8.2. Earthing bars

Separate insulated earthing bars shall be provided for extra low voltage and low voltage circuits on each vehicle.

The extra low voltage and low voltage earthing bars shall be directly connected to the vehicle body earthing system.

Each electrical circuit or equipment shall have a separate negative or neutral cable connected directly to its respective earthing bar.

Low voltage power sources shall have the neutral and negative lines connected to the vehicle body earthing system.

### 8.3. Earth bar terminal connections

All earthing bar terminal connections shall be of a bolted connection designed to withstand unscrewing forces when subjected to shock and vibration conditions in compliance with IEC 61373 *Railway applications - Rolling stock equipment - Shock and vibration tests*.

Similar circuits, such as circuits of the same voltages, shall be grouped together on earth bar terminals.

Alternating current and direct current circuits and circuits with different voltages shall not be connected to the same earth bar terminal bolted connection.
The vehicle body earthing terminals shall use a permanent screw stud design fixed to the main structural elements that are electrically contiguous with other structural elements.

All internal and external conductive body panels shall be connected electrically to the vehicle body earthing circuit through direct contact or wired connections.

9. **Electrical equipment requirements**

This section details requirements and recommendations for specific electrical equipment.

All electrical equipment shall comply with the relevant requirements of the following standards:

- IEC 61373 *Railway applications - Rolling stock equipment - Shock and vibration tests*
- EN 50155:2007 *Railway Applications - Electronic Equipment Used on Rolling Stock*

9.1. **Electric traction motors**

Electric traction motors for LRVs shall comply with the following standards as applicable:

- IEC 60349-1 *Electric traction - Rotating electrical machines for rail and road vehicles - Part 1: Machines other than electronic converter-fed alternating current motors*
- IEC 60349-4 *Electric traction - Rotating electrical machines for rail and road vehicles - Part 4: Permanent magnet synchronous electrical machines connected to an electronic converter*

9.2. **Electrical cables**

All electrical cables shall be in accordance with T MU RS 00164 ST.

The colour coding and marking of cables shall be in accordance with T MU RS 00164 ST.

9.3. **Extra low voltage contactors and switches**

Electrical contacts in switches, relays and contactors in control and power circuits are subject to potential burning and electrical corrosion when breaking dc current which may lead to premature failure including intermittent failures. When selecting switches and contactors, the magnitude and the inductive time constants of the current to be interrupted shall be taken into account to ensure reliability of the electrical contacts.

Switches and contactors with voltage ratings of extra low voltage and below shall be selected to provide an operating life greater than the specified life of the vehicle.
The auxiliary contacts of contactors, intended for switching smaller control circuit currents, shall not be possible to be mistakenly used in lieu of the main power contacts of the contactor.

9.4. Power contactors

Power contactors with voltage ratings of low voltage and above shall be provided with a maintenance plan to prevent in-service failures due to eventual degradation of the contacts. Power contactors with replaceable contact tips shall be provided with the necessary tools and instructions to ensure proper tightening and alignment of the contact tips. All arc chute components shall have adequate resistance to erosion and burning from the arcs to which they might be subjected.

9.5. High-speed circuit breakers and line-switches

High speed circuit breakers and line switches requirements are detailed in T LR RS 11001 ST Onboard Main Power and Auxiliary Power Supply Systems Light Rail Vehicle.

9.6. Surge arrester

Surge arrester requirements are detailed in T LR RS 11001 ST Onboard Main Power and Auxiliary Power Supply Systems Light Rail Vehicle.

9.7. Coil windings

The coil windings of inductors and transformers shall be continuously rated and physically designed for suitability in the railway environment. Insulated coils shall be fully impregnated to prevent the ingress of fluids and moisture. The coil conductor and its insulation system shall have mechanical protection to prevent any chafing or movement damage caused by normal installation, removal or storage conditions.

9.8. Cable connectors and plug-in components

All cable connectors and plug-in components including relays, printed circuit boards, electronic cards and electrical modules shall comply with the following requirements:

- cable connectors and plug-in components shall use a mechanical restraining system to prevent dislodgement under railway shock and vibration conditions defined in IEC 61373
- electrical contacts of cable connectors and plug-in components shall be adequately safeguarded to protect from damage during transportation and handling
- incorrect insertion of a plug or plug-in component shall be prevented by the use of a guide, shield or otherwise
where non-interchangeable plug-in devices have similar plug-in components they shall be provided with a means to prevent them from being inserted in the wrong position or equipment.

Upon connection, circular cable connectors shall produce an audible or otherwise mechanical feedback that is able to be sensed by the technician to indicate that the connector has been fully engaged and is locked into position.

9.9. **Calibrated devices**

Electrical equipment requiring calibration or adjustments shall be provided with an adjusting mechanism and method to protect against shock and vibration as defined in IEC 61373 and accidental readjustment.

Electrical equipment requiring calibration or adjustments shall be provided with a technical manual and any special equipment required for calibration.

9.10. **Control panel switches, push buttons and indicators**

Control panel switches, including push buttons and key switches, and indicators shall use a design that prevents tampering and unauthorised removal.

All visual indicating lights shall be LED-based and shall be compatible with the power supply voltage spikes and over-voltage characteristics.

Control panel switches, including push buttons and key switches, and indicators shall be selected to provide an operating life equal to the specified life of the vehicle.

9.11. **Circuit breakers**

All circuit breakers shall be of the direct acting overcurrent magnetic type.

Circuit breakers shall be installed such that the operating lever shall be down in the 'off' or 'tripped' position. The 'off' position shall be clearly marked.

Each circuit breaker shall be labelled with the circuit it protects.

Circuit breakers shall comply with the following standards:

- IEC 60077-3 *Railway applications - Electric equipment for rolling stock - Part 3: Electrotechnical components - Rules for DC circuit-breakers*
9.12. **Fuses**

Traction supply voltage fuses shall comply with IEC 60077-5 *Railway Applications – Electric equipment for rolling stock - Part 5: Electrotechnical components - Rules for HV fuses.*

A fuse tester using extra low voltage test voltage shall be provided in the same enclosure as the battery fuses.

Spare fuses of each type shall be mounted in unconnected fuse holders adjacent to each fuse panel or group of panels in one location.

When determining the number of spare fuses supplied for each type of fuse, the probability of multiple fuse failures of the same type in the same or related circuit shall be taken into account, to ensure the availability of same fuse type.

9.13. **Resistors**

Traction supply voltage resistors or heavy current (a current in excess of 30 A) resistors shall be prevented from shorting out in overload conditions in normal service.

Resistors greater than a 5 W rating shall be of the wire or strip wound type that is encapsulated to provide mechanical protection and contaminants protection.

The adjustable mechanism of adjustable resistors shall be secured and protected against vibration in the light rail operating environment.

Fixed resistors of standard resistance values shall be used with the value, power rating and tolerance clearly marked.

9.14. **Capacitors**

Capacitors for power electronics including filter circuits shall comply with IEC 61881 *Railway applications - Rolling stock equipment - Capacitors for power electronics.*

Electrolytic capacitors shall not be used as single-phase capacitor starter motors.

Where capacitors are used as part of a surge suppression circuit, the required capacity shall be available at the surge frequency.

Discharge resistors shall not be integrated with suppression capacitors.

Capacitors in power supplies shall be over rated where applicable or selected to ensure the specified operating life span.

9.15. **Traction and auxiliary battery systems**

Traction and auxiliary battery systems requirements are detailed in T LR RS 11001 ST *Onboard Main Power and Auxiliary Power Supply Systems Light Rail Vehicle.*
9.16. Electrical measuring instruments

All analogue electrical measuring instruments and their accessories shall comply with IEC 60051-1 Direct acting indicating analogue electrical measuring instruments and their accessories - Part 1: Definitions and general requirements common to all parts.

All analogue electrical measuring instruments shall have a true zero and the movement needle be suitably damped to prevent vibrations in all direction in light rail vehicle operating conditions.

All instruments and their parts shall be protected from tampering.

All instruments shall have accuracy greater than ± 0.75% of the measuring range of the instrument.

Requirements for onboard energy metering are detailed in T LR RS 11001 ST Onboard Main Power and Auxiliary Power Supply Systems Light Rail Vehicle.