NSW GOVERNMENT

TS 04081:1.0

T LR RS 00117 ST

Standard

Electrical Circuits and Equipment for Light Rail Vehicles

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Document information

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Document history

Revision	Effective date	Summary of changes
2.0	07/11/2017	Second issue with the designation T LR RS 00117 ST– Updates of general requirements. Removal of requirements for the onboard main power supply.
1.0	01/06/2023	First version issued with the new designation TS 04081. No technical changes to previous content in this issue as this is a reconfirmation of the document.

Preface

The AMB 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 AMB 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, TS 04087 (T LR RS 11001 ST).

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 aims to ensure that the light rail vehicles (LRVs) used by TfNSW in their operations meet the minimum requirements for performance and safety.

There are no technical changes to previous content in this issue as this is a reconfirmation of the document.

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1 Scope

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.

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 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 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 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

TS 03786 (T LR EL 00007 ST) *Traction Power Supply Infrastructure and Light Rail Vehicle Interface*

TS 04084 (T LR RS 01701 ST) *Mounting and Installation of Electrical Equipment for Light Rail Vehicles*

TS 04087 (T LR RS 11001 ST) *Onboard Main Power and Auxiliary Power Supply Systems for Light Rail Vehicles*

TS 03998 (T LR RS 17010 ST) *Light Rail Vehicle Fire Safety*

TS 01506 (T MU AM 01003 ST) *Development of Technical Maintenance Plans*

TS 04000 (T MU RS 00164 ST) *Cables for Passenger Rolling Stock*

TS 04002 (T MU RS 17001 ST) *Environmental Conditions for Rolling Stock*

TS 04003 (T MU RS 17002 ST) *Prohibited and Restricted Materials*

4 Terms, definitions and abbreviations

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

ac alternating current

AMB Asset Management Branch

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
- EN 50155
- EN 50343
- IEC 60077-1
- IEC 60034-1
- TS 04084 (T LR RS 01701 ST).

5.1 Electromagnetic compatibility

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
- EN 50121-3-1
- EN 50121-3-2.

5.2 Prohibited materials requirements

Materials used in rolling stock electrical circuitry and electrical equipment shall comply with the requirements of TS 04003 (T MU RS 17002 ST).

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 TS 03998 (T LR RS 17010 ST).

Electrical cable fire performance requirements shall at a minimum comply with TS 04000 (T MU RS 00164 ST).

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 with the aim to ensure that the specified reliability and life span are achieved.

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 TS 04002 (T MU RS 17001 ST).

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, 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 cannot 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 achieve 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 TS 01506 (T MU AM 01003 ST).

5.8 General circuit voltages

Vehicle control and lighting circuits shall not exceed extra low voltage.

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.

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 TS 03786 (T LR EL 00007 ST).

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.

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 TS 04087 (T LR RS 11001 ST).

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 verify 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.

> Note: 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 so that the load at each phase remains 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 achieve 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 with the aim 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 TS 04087 (T LR RS 11001 ST):

- 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 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 aim to ensure that 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.

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
- EN 50155:2007.

9.1 Electric traction motors

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

- IEC 60349-1
- IEC 60349-2
- IEC 60349-4.

9.2 Electrical cables

All electrical cables shall comply with TS 04000 (T MU RS 00164 ST).

The colour coding and marking of cables shall comply with TS 04000 (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 can 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 with the aim 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 achieve the correct 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 TS 04087 (T LR RS 11001 ST).

9.6 Surge arrester

Surge arrester requirements are detailed in TS 04087 (T LR RS 11001 ST).

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. They 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
- IEC 60077-4.

9.12 Fuses

Traction supply voltage fuses shall comply with IEC 60077-5.

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.

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.

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 achieve the specified operating life span.

9.15 Traction and auxiliary battery systems

Traction and auxiliary battery systems requirements are detailed in TS 04087 (T LR RS 11001 ST).

9.16 Electrical measuring instruments

All analogue electrical measuring instruments and their accessories shall comply with IEC 60051-1.

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 TS 04087 (T LR RS 11001 ST).