Technical Note – TN 023: 2018

Subject: Change to unrestricted free height of pantographs

This technical note is issued by the Asset Standards Authority (ASA) as an update to T HR RS 00850 ST RSU Appendix E – Rolling stock 1500 V dc overhead power supply interface requirements, version 1.0.

The updates include amendments to the requirements in Section 5.1.

1. Section 5.1. Performance characteristics of the pantograph

Section 5.1 shall read as follows:

The pantograph shall remain in continuous electrical contact with the contact wire at any speed up to the maximum operating speed plus any design over speed (typically 10%), as specified in the vehicle’s train performance specification, and the contact wire rising or falling gradients as referenced in EP 08 00 00 01 SP.

The pantograph design shall take into account the dynamic lateral movement caused by track geometrical deviation and train body movement as detailed in EP 08 00 00 01 SP.

The pantograph should be capable of rising to its unrestricted full height in eight seconds or less under static conditions.

The pantograph shall be capable of falling from its full height to a position within the applicable rolling stock outline, excluding the area designated for the pantograph, within three seconds of the initiating operation.

The pantograph shall be fitted with an automatic drop device that causes the pantograph to lower automatically following any failure of the collector head. Such failures shall include, but are not limited to the following:
• If the pantograph exceeds 6000 mm height above the rail, the pantograph shall automatically return to the collapsed position within three seconds.

• Pantographs shall have a minimum unrestricted free height of 6000 mm above railhead level on level track when any height limit function is disabled.

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RSU Appendix E – Rolling stock
1500 V dc overhead power supply interface requirements

Version 1.0
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Standard governance

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Document history

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Preface

The Asset Standards Authority (ASA) is an independent unit within Transport for NSW (TfNSW) and is the network design and standards authority for defined NSW transport assets.

The ASA is responsible for developing engineering governance frameworks to support industry delivery in the assurance of design, safety, integrity, construction, and commissioning of transport assets for the whole asset life cycle. In order to achieve this, the ASA effectively discharges obligations as the authority for various technical, process, and planning matters across the asset life cycle.

The ASA collaborates with industry using stakeholder engagement activities to assist in achieving its mission. These activities help align the ASA to broader government expectations of making it clearer, simpler, and more attractive to do business within the NSW transport industry, allowing the supply chain to deliver safe, efficient, and competent transport services.

The ASA develops, maintains, controls, and publishes a suite of standards and other documentation for transport assets of TfNSW. Further, the ASA ensures that these standards are performance based to create opportunities for innovation and improve access to a broader competitive supply chain.

This document supersedes RailCorp standard ESR 0001-E - Minimum Operating Standards for Rolling Stock – Appendix E - Specification for 1500 V dc Traction Supply, Version 1.2. The changes to previous content include the following:

- replacement of RailCorp organisation roles and processes with those applicable to the current ASA organisational context
- minor amendments and clarification to content
- conversion of the standard to ASA format and style
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1. Introduction

The 1500 V dc electrical traction system used on the RailCorp network consists of the fixed components that enable power to be supplied to trains for traction and auxiliary supply. It may also accept power back to the network when regenerated by the train.

The electrical interface is the interaction of the traction supply with the vehicle based systems and components.

Influencing factors including the following:

- magnitude of electrical load – stationary and moving, including: the type of train, the current required for powering, the current required for auxiliaries, the numbers of trains operating (that is, the timetable), and the speed of operation
- traction system capacity including: fault levels, protection types, and rate of rise of current
- train mounted equipment including: protection, in-rush current, and input filter characteristics

The mechanical interface is the pantograph complete, including horns, and the catenary and contact wire and deals with the ability to transfer the required power across the interface.

Factors that influence the design of the mechanical interface include the following:

- movement of the overhead wiring (OHW), including contact wire stagger, ambient temperature and crosswind
- characteristics of the pantograph
- characteristics of the collectors on the pantograph
- the number of pantographs on a train, and their spacing

The correct operation of the power supply system can only be determined when all these factors are known.

2. Reference documents

International standards

EN 50119 Railway applications - Fixed installations - Electric traction overhead contact lines
EN 50367 Railway applications - Current collection systems - Technical criteria for the interaction between pantograph and overhead line (to achieve free access)

Transport for NSW standards

EP 00 00 00 13 SP Electrical Power Equipment - Design Ranges of Ambient Conditions
EP 08 00 00 01 SP Overhead Wiring Standards for the Electrification of New Routes
3. **Existing electrical infrastructure system**

The main elements of existing electrical infrastructure on the RailCorp network that trains shall be required to interface with include the following:

- standard power supply
- protection systems for overhead wiring
- specified fault levels and ratings
- a capacity for power regeneration
- surge arresters and transients

3.1. **Supply**

T HR EL 00001 TI *RailCorp Electrical System General Description* provides basic general background to electrical infrastructure and assets located within the Sydney metropolitan rail area.

The 1500 V dc overhead traction system is fed from substations supplied from 33 kV transformers and 33 kV supply feeders, from the 50 Hz ac system of the New South Wales grid.

Silicon diode rectifiers are used to covert the ac voltage to dc. Six pulse and twelve pulse rectification is used.

Failure of one or more diodes can result in 50 Hz voltages appearing on the 1500 V dc.
Ratings of the rectifiers range from 2000 kW to 5000 kW continuous.

The majority of substations are fitted with shunt harmonic filters tuned to 600 Hz and 1200 Hz. However, there remain in service a small number of substations that have filters tuned to 150 Hz, 300 Hz, and 900 Hz, depending upon the harmonics produced. These are progressively being phased out of service.

The voltage conditions are as defined in EP 90 20 00 02 SP - 1500V System Voltage Ratings.

### 3.2. Protection

Overhead wiring protective devices are sensitive to both current amplitude and rate of rise of current.

Circuit breaker steady state settings are typically 3 kA to 6 kA. OHW sections are usually fed from both ends. Direct current circuit breaker (DCCB) trip levels are sensitive to rate of rise of current. Rates of rise less than 60 kA/s have no effect on the trip level. Above this rate of rise, the trip level decreases to 60% of the steady state setting, at 500 kA/s.

Delta I relays are installed on most feeders as a backup to the dc circuit breakers. They are intended to detect limited arcing faults. They are usually set at 2 kA or above.

### 3.3. Fault levels

Table 1 provides some fault levels and current ratings specified on the RailCorp 1500 V traction supply system.

<table>
<thead>
<tr>
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<th>Maximum fault</th>
<th>Minimum fault</th>
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<tr>
<td>Prospective fault current level at train</td>
<td>75,000 A</td>
<td>3000 A</td>
</tr>
<tr>
<td>Corresponding circuit time constant</td>
<td>12 ms</td>
<td>25 ms</td>
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<tr>
<td>Rate of rise of current</td>
<td>6,000,000 A/s</td>
<td>120,000 A/s</td>
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<tr>
<td>SS/SH fault clearing time (max)</td>
<td>15 ms</td>
<td>150 ms</td>
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<tr>
<td>Max let through current</td>
<td>30,000 A</td>
<td>3000 A</td>
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For further information see specification, EP 90 20 00 01 SP – 1500V DC Equipment Current Ratings.

### 3.4. Regeneration

The traction system is capable of accepting power from regenerating trains, only when there are other trains capable of using the regenerated energy. This is usually the case for multiple unit train operation; however there is no guarantee that the traction system will be receptive at any time.
A small number of substations are equipped with energy dissipating resistances to dissipate energy regenerated by trains, when no other train loads are nearby.

### 3.5. Surge arresters and transients

Transient voltages ranging between 3000 V and 5000 V have been measured between contact wire and rail, when testing high speed circuit breakers for clearing dc faults.

Substations and sectioning huts are fitted with surge arresters with a breakdown voltage of 2100 V.

### 4. Existing mechanical infrastructure

Trains shall interface with the overhead wiring parameters including contact wire position heights and gradients, and vertical, horizontal, and lateral forces, and system contact wire tension.

Various combinations of catenary contact systems are applied on the NSW electrified network.

The catenary contact systems, including their cross-sectional areas, are as detailed in standard EP 08 00 00 16 SP – *Designations of OHW Conductor Systems*.

The contact wire material is given in standard EP 08 00 00 16 SP.

#### 4.1. Contact wire position

Under the worst condition of high temperature and cross wind, the design maximum displacement of the contact wire from the superelevated centre line is given in EP 08 00 00 01 SP *Overhead Wiring Standards for the Electrification of New Routes*.

The contact wire heights above rail are given in EP 08 00 00 01 SP.

The worst contact wire gradient is given in EP 08 00 00 01 and in EP 08 00 00 15 SP *Overhead Wiring Construction and Commissioning*.

The maintenance trigger for in service OHW is given in EP 08 00 00 02 SP.

The running surface of the contact wire contains mechanical discontinuities which can subject pantographs to vertical forces and horizontal forces in the direction of the pantograph travel. These forces are generally attributed to the following contact wire characteristics and components:

- splices
- section insulators
- kinks
Diverging and converging contact wire can also subject pantographs to lateral forces at right angles to the direction of pantograph travel. The lateral forces are caused by the pantograph horns striking the contact wires. Generally, such wires would not contact the pantograph horn more than 200 mm below the top running surface of the pantograph. The converging situation is more severe than the diverging situation, the pantograph forces being a function of vehicle speed, the difference in wire heights, the angle of incidence of wire on the pantograph horn, and the pantograph pressure.

4.2. Contact wire tension

The contact wire tension is influenced by the type of conductor systems used in the design and variations in the ambient temperatures under which they operate.

The range of conductor systems and the design contact wire tension at the design temperature for each system is given in EP 08 00 00 16 SP.

The ranges of ambient conditions within which OHW equipment used on the high voltage and traction networks is designed to operate is given in EP 00 00 00 13 SP Electric Power Equipment – Design Ranges of Ambient Conditions.

The allowable contact wire tension change for regulated overhead wiring is given in EP 08 00 00 01 SP.

5. Pantograph requirements

Smooth reliable operation of electric trains requires continuous electrical contact between the pantograph current collection device and the contact wire.

If the pantograph or carbon collector strip becomes damaged or broken resulting in the pantograph returning to the collapsed position, its parts shall not foul or cause damage to the overhead system.

Pantographs on electric multiple unit trains shall be placed so that when the cars are arranged in a train, there shall be a minimum of 20 metres between any two pantographs to avoid excessive upward thrust by pantographs on to the OHW.

In the case of electric locomotive operations, the maximum number of pantographs that can be raised for any catenary contact systems, as detailed in EP 08 00 00 16 SP, is given in EP 08 00 00 17 SP Overhead Wiring Conductor System Selection.

5.1. Performance characteristics of the pantograph

The pantograph shall remain in continuous electrical contact with the contact wire at any speed up to the maximum operating speed plus any design over speed (typically 10%), as specified in
the vehicle’s train performance specification, and the contact wire rising or falling gradients as referenced in EP 08 00 00 01 SP.

The pantograph design shall take into account the dynamic lateral movement caused by track geometrical deviation and train body movement as detailed in EP 08 00 00 01 SP.

The pantograph should be capable of rising to its unrestricted full height in eight seconds or less under static conditions.

The pantograph shall be capable of falling from its full height to a position within the applicable rolling stock outline, excluding the area designated for the pantograph, within three seconds of the initiating operation.

The pantograph shall be fitted with an automatic drop device that causes the pantograph to lower automatically following any failure of the collector head. Such failures shall include, but are not limited to the following:

- dislodged, damaged, worn to condemning, or broken contact collector strip
- entanglement of the collector head with the contact wire or support apparatus
- contact with an obstruction or other object

If the pantograph exceeds 6100 mm height above the rail, the pantograph shall automatically return to the collapsed position within 3 seconds.

Pantographs shall have a minimum free height of 6100 mm above railhead level on level track when any height-limit function is disabled.

5.1.1. Physical characteristics

Pantographs have physical characteristic requirements regarding positioning, movement, dimensions, drag, and resistance to damage.

Pantographs shall be adjustable for upwards static thrust as tabled in EP 08 00 00 01 SP and be set at the minimum thrust consistent with achieving the required dynamic performance.

Where a supplier proposes to use alternative system settings, an assessment of dynamic performance shall be provided by the supplier, if requested by the purchaser.

When in the lowered position, all parts of the pantograph shall fit within the applicable rolling stock outline.

The horizontal drag of the pantograph on the contact wire shall not exceed 20 N from 0 km/h to the maximum operating speed plus any design over speed (typically 10%), as specified in the vehicle’s train performance specification.
The total pantograph dynamic upward thrust shall not increase by more than 60 N at any train speed up to the maximum operating speed plus any design over speed (typically 10%), and subject to non train generated winds of up to 100 km/h from any direction.

5.1.2. Dimensional characteristics

Drawing CV0131343 Standard Pantograph Profiles – Suburban/Interurban and Locomotive Rolling Stock provides dimensioned pantograph profiles for existing trains operating on the TfNSW network. Refer to T HR RS 00870 ST RSU Appendix G - Drawings, for drawing CV0131343.

Alternative profiles may be used provided compliance to EP 08 00 00 01 SP and EP 08 00 00 02 SP Overhead Wiring Maintenance Standards can be demonstrated to the purchaser.

The design of particular types of section insulators used on the TfNSW network precludes the use of bowed pantograph profiles. Only flat pantograph profiles are compatible.

5.1.3. Pantograph current draw

The maximum current drawn by a pantograph shall not exceed limits imposed by the traction supply infrastructure.

The current draw of a stationary train drawing current from the OHW to supply auxiliary loads for extended periods, shall comply with the requirements of EN 50119. The ability for the pantograph to meet this performance requirement shall be tested in accordance with EN 50367.

The OHW temperature at the point of contact with any single pantograph, when subjected to the maximum current drawn by a stationary train, under any operating condition, shall not exceed 110°C for 30 minutes and shall not exceed 90°C thereafter, as indicated in the following diagram Figure 1:

![Figure 1 - Maximum OHW temperature at the point of contact with any single pantograph](image-url)
5.2. Pantograph materials requirements

The material used for the part of the pantograph that makes contact with the overhead wiring (OHW) has operation, service life, and environmental and safety requirements.

The composition of the contact collector strip material shall be optimised for the vehicle operating characteristics and maximise service life for both the contact collector strip and the contact wire.

Any carbon insert shall not include any lead, or any other heavy metals.

*By 2014, the majority of trains operating on the Sydney network used Morgan Advanced Materials Grade MY 258A2 for the carbon contact material. Operating experience across the fleet of these trains has returned a carbon life in excess of 100,000kms.*

6. Train-borne protection equipment

Trains shall have high speed circuit breakers and shall not cause excessive auxiliary in-rush current to the 1500 V dc system, in line with requirements in Section 6.2.

6.1. Train high speed circuit breaker

Each power car or locomotive shall be fitted with a high speed circuit breaker (HSCB) to detect and clear faults. This HSCB should ideally clear any fault before the substation and sectioning hut DCCBs operate. The data provided in Section 3.2 shall be used to determine the requirements of the train HSCB.

6.2. Auxiliary in-rush current

Train equipment shall limit the magnitude of the total in-rush current to 1000 A for any one incidence, with a maximum rate of rise of 60,000 A/s. This in-rush may be repeated at half second intervals.

A high rate of rise of current will trip direct current circuit breakers (DCCB). Raising all the train pantographs simultaneously, shall not cause sufficient in-rush current to trip the substation or sectioning hut DCCB.

Train equipment shall limit the magnitude of the total in-rush current so that closing an open substation or sectioning hut DCCB onto a line with one or more stationary trains shall not cause sufficient in-rush current to trip the DCCB.

7. Power regeneration requirements

There is no requirement for trains to feed energy back to the grid.
If a train provides regenerative power, train regenerated voltages shall not exceed 2050 V.

8. Information to be provided to TfNSW

The following information shall be provided to TfNSW for any new type of equipment, before being introduced onto the network.

- Magnitude of electrical load – stationary, powering and regenerating, including:
  - the type of train
  - the number of pantographs
  - the maximum steady state current required for powering on the steepest track grades to be encountered with the heaviest loads
  - the maximum steady state current required for auxiliaries
  - the magnitude of any traction system or auxiliary system step current drawn from the traction supply and its rate of rise
  - the numbers of trains operating (that is, the timetable)
  - the speed of train operation
  - tractive effort vs speed curve