TS 00103.3:1.0

Standard

25 kV AC Traction System

Part 3: Overhead Wiring System

Issue date: 10 April 2024

Effective date: 10 April 2024

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Document information

Owner:	Director Energy Networks and Systems Asset Management Safety Environment and Regulation
Mode:	Metro
Discipline:	Electrical

Document history

Revision	Effective date	Summary of changes
1.0	10 April 2024	First issue

Preface

This standard is the first issue as TS 00103.3:1.0.

This document sets out requirements for the design of 25 kV ac OHW systems, which apply to new classic installations as well as any upgrades or modifications to those systems.

This document forms part of the TS 00103 series of standards related to 25 kV ac traction systems. The series has been developed to establish a common approach for the development and installation of 25 kV ac traction systems in NSW. This document should be read in conjunction with TS 00103.1 and TS 00103.2.

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1 Scope

This standard sets out the requirements for the design of 25 kV ac OHW systems.

This document covers flexible OHW systems (both contact and catenary, and trolley wire subtypes) and ROCS (including retractable ROCS).

2 Application

This standard applies to the OHW on 25 kV ac traction systems. This standard is applicable to all new 25 kV ac OHW installations and any future upgrades or modifications to the 25 kV ac OHW.

The following legislation contains requirements applicable to this document:

- Electricity Supply Act 1995
- Rail Safety National Law (NSW) 2012
- Work Health and Safety Act 2011.

3 Referenced documents

The following documents are cited, or relevant to, the text. For dated references, only the cited edition applies. For undated references, the latest edition of the referenced document applies.

International standards

DIN 48201–2 Bronze stranded conductors

EN 50122–1:2022 Railway applications – Fixed installations – Electrical safety, earthing and the return circuit Part 1: Protective provisions against electric shock

EN 50124–1 Railway applications – Insulation coordination Part 1: Basic requirements – Clearances and creepage distances for all electrical and electronic equipment

EN 50149:2012 Railway applications – Fixed installations – Electric traction – Copper and copper alloy grooved contact wires

EN 50152–2 Railway applications – Fixed installations – Particular requirements for alternating current switchgear. Part 2: Disconnectors, earthing switches and switches with nominal voltage above 1 kV

EN 50182 Conductors for overhead lines – Round wire concentric lay stranded conductors

EN 50183 Conductors for overhead lines – Aluminium-magnesium-silicon alloy wires

EN 50317 Railway applications – Current collection systems – Requirements for and validation of measurements of the dynamic interaction between pantograph and overhead contact line

EN 50318 Railway applications – Current collection systems – Validation of simulation of the dynamic interaction between pantograph and overhead contact line

I.S. EN 50119:2020 Railway applications – Fixed installations – Electric traction overhead contact lines

I.S. EN 50367:2020 Railway applications – Fixed installations and rolling stock – Criteria to achieve technical compatibility between pantographs and overhead contact line

Australian standards

AS/NZS 1170.1 Structural design actions Part 1: Permanent, imposed and other actions

AS/NZS 1170.2 Structural design action Part 2: Wind actions

AS 1746 Conductors – Bare overhead – Hard-drawn copper

AS 2159 Piling – Design and installation

AS 3600 Concrete structures

AS/NZS 4680 Hot-dip galvanized (zinc) coatings on fabricated ferrous articles

AS/NZS 7000 Overhead line design

Transport for NSW standards

TS 00103.1 25 kV AC Traction Systems Part 1: Traction Power System

TS 00103.2 25 kV AC Traction Systems Part 2: Earthing and Bonding

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

Legislation

Rail Safety National Law 2012 (NSW)

Work Health and Safety Act 2011

4 Terms, definitions and abbreviations

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

ac alternating current

AMB asset management branch

AT automatically tensioned

catch point type of turnout used to protect main railway lines from unauthorised vehicle movements

contact point point of the mechanical contact between a collector head's contact strip and a contact wire

catenary wire conductor from which the contact wire is suspended

contenary wire piece of contact wire spliced into the catenary wire; used to minimise the chance of wire stranding in the event of a flashover

current collector zone (CCZ) zone whose limits are in general not exceeded by an energised collector no longer in contact with the contact line or broken collector and its fragments

CW contact wire; contact line placed above (or beside) the upper limit of the vehicle gauge and supplying vehicles with electric energy through roof-mounted current collection equipment

dropper vertical wire by which the contact wire is suspended from the catenary wire

encroachment perpendicular distance from the contact plane to the highest point of the pantograph head (see Figure 1)

FED fixed earthing device

flexible OHW flexible overhead wiring system

FSAM free standing anchor mast that does not need to be back-anchored

jumper short length of conductor(s) not under mechanical tension, making an electrical connection between two or more conductors or other electrical equipment

knuckle registration assembly designed to provide staggering at an along track distance from an OHW structure, or where it is not possible to fit a conventional registration arrangement

lateral deviation deviation of the contact wire from the track centre line

MPA mid point anchor

OHEW overhead earth wire

OHW overhead wiring

OHW system the support network for supplying electrical energy from substations to electrically powered traction units; it includes the overhead contact line

open route sections of OHW that are installed to their normal system parameters, and where those parameters are not influenced by infrastructure limitations caused by discrete features, such as crossovers, contact wire gradients, low overbridges and tunnels

pantograph interface between the rolling stock and the OHW system. It is a device located on top of a rail vehicle which provides a mechanical and electrical interface with the overhead contact wire by means of a sliding contact

pantograph horn the curved part at either end of the pantograph head

pre-sag amount by which the contact wire is designed to hang below the height as measured on a line mid-way between the first and last dropper of any span

RAM reliability, availability and maintainability

ROCS rigid overhead conductor system

RROCS retractable rigid overhead conductor system

RSC return screening conductor

SCADA supervisory control and data acquisition

SI section insulator; sectioning point formed by insulators inserted in a continuous run of a contact wire, with skids or similar devices to maintain continuous electrical contact with the collector

SFAIRP so far as is reasonably practicable

SLD single line diagram

stagger displacement of the contact wire from the track centreline at successive supports to avoid localised wear of the pantograph head

stagger sweep rate rate of across-track movement of the contact wire across the pan, expressed in mm per metre of span

STC single track cantilever

sweep lateral movement of the contact wire across the pantograph in the course of its travel between any two registration points

system depth at support structure the system depth at a support point

system design the matching of mechanical and electrical parameters to a railway performance specification, to produce basic wire run parameters (wire sizes and tensions) – with a typical output being a system description manual

TfNSW Transport for New South Wales

TSCs track sectioning cabins

TTC two track cantilever

uplift vertical upward displacement of the contact wire due to the force produced from the pantograph

UTO unattended train operation

5 System types

5.1 General

The OHW types set out in Section 5.2 and Section 5.3 shall be employed for 25 kV ac electrification.

5.2 Flexible overhead wiring systems

5.2.1 Contact and catenary

Contact and catenary systems consist of a single contact wire supported from a catenary wire via vertical droppers. The system is profiled such that the contact wire sag between OHW system support structures is managed to a design value.

The contact and catenary wires shall be automatically tensioned to compensate for the thermal expansion of the conductors and to maintain the design tension across the design temperature range.

5.2.2 Trolley wire

Trolley wire systems consist of a single contact wire supported directly from the OHW structures, with no catenary wire. An additional contact wire may be added where required to increase the power rating of the system.

The contact wire(s) shall be automatically tensioned to compensate for the thermal expansion of the conductors and to maintain the design tension across the design temperature range.

Due to the lack of catenary wire, the contact wire is free to sag under its own weight. For this reason, trolley wire systems shall not be used in areas other than low-speed areas. Subject to this standard, other systems may be used in low-speed areas.

In the event of a wire break, the single contact wire can rebound over a wide area, due to the lack of restraint that would otherwise be provided by a separate catenary wire. For this reason, trolley wire systems shall not be used in public areas, such as stations, and should be restricted in low-speed areas such as sidings and maintenance centres.

5.3 Rigid overhead conductor systems

5.3.1 Rigid overhead conductor systems

ROCS consist of a single contact wire continuously supported by sections of aluminium extruded profile, joined to form a conductor bar.

Due to the nature of ROCS, the reduced uplift and sag (compared to a flexible overhead contact wire) enable a reduction in required tunnel diameter.

Due to the continuous support of the contact wire provided by the aluminium conductor bar, it is not necessary to apply mechanical tension to the contact wire, and thus, there is no requirement for tensioning equipment to be provided.

5.3.2 Retractable rigid overhead conductor systems

RROCS is a subsystem of the ROCS.

The systems are similar, however, the RROCS can be retracted and reapplied as required in maintenance centres.

5.4 System selection

The preferred options for system selection are outlined in Table 1.

Table 1 – OHW selection preferences

System	Selection preferences
ROCS	Tunnels – being compact and solid, this system will require less height in tunnels and other above track structures.
RROCS	Maintenance buildings – to facilitate maintenance on the top of rail vehicles; it is retractable to ease maintenance tasks.
Flexible OHW – contact and catenary	Outside of tunnels – where there is no space limitation, it is the most practical and economical system that regulates tension through out several conditions.
Flexible OHW – trolley wire	Outside of tunnels in low-speed areas – not permitted in public areas such as stations (see Section 5.2.2). It may be used in locations such as sidings, depots and maintenance buildings.

The selected OHW for any project shall be based on factors including but not limited to the following:

- vehicle characteristics
- track layout
- environmental conditions
- traction power supply
- line speed
- interface with existing installations
- construction methodology
- future performance requirements
- asset management strategy
- whole of life cost.

6 Performance requirements

6.1 Environmental conditions

The OHW shall be designed to meet the performance required within this standard, under the environmental operating conditions outlined in TS 03744.

6.2 Electrical performance

The current carrying capacity of the OHW shall meet the requirements of the traction power system design.

The level of insulation shall be determined by an insulation coordination study, taking into account air pollution as a factor. See TS 00103.2 for further details on insulation coordination.

6.2.1 Required current rating

The OHW shall be designed for the electrical loads defined in the traction power system design, under all operating environmental conditions as defined in TS 03744.

So that the mechanical properties of the conductor materials are not impaired by temperature rise, the OHW shall be designed in accordance with Clause 5.1.2 in I.S. EN 50119:2020.

6.2.2 Resistance of conductors

The resistance values for individual conductors of the OHW shall be determined from the standards listed in Table 2.

Table 2 – Standards for various OHW wire types

Wire type	Standard
Copper stranded catenary wires	AS 1746
Bronze stranded catenary wires	DIN 48201–2
Copper and copper alloy grooved contact wires	EN 50149:2012
Aluminium or steel wires	EN 50182
Heat-treated aluminium-magnesium-silicon alloy	EN 50183

6.3 Design life

The design life of the OHW equipment shall be in accordance with Clause 4.7 of I.S. EN 50119:2020

The design life of the wearing parts, such as the section insulator runners and contact wire, will vary depending on several conditions such as the number of pantograph passes and OHW configuration.

The designer shall provide details of maintenance activities necessary to achieve this design life and any components of the system which will need to be replaced during this design life.

6.4 Current collection quality

6.4.1 General

Safety and performance of train operation and wear of the contact strips and contact wire are influenced by the dynamic interaction between the pantograph and the overhead contact wire.

The performance characteristics of the OHW, when interacting with the pantograph, shall be assessed in static and dynamic conditions. Dynamic behaviour shall be predicted in the design phase by computer simulation. Dynamic behaviour shall be verified on the installed OHW with measurements.

6.4.2 Assessment criteria

The contact wire shall be designed and installed to ensure acceptable current collection performance at all operating speeds and while at a standstill.

Compliance with the requirements for dynamic behaviour shall be verified in accordance with I.S. EN 50367:2020, Clause 7.3 by assessment of contact wire uplift at the support (see Section 6.4.6 of this document).

The dynamic behaviour and quality of current collection assessment criteria shall be in accordance with I.S. EN 50367:2020, Clause 9.

6.4.3 Mathematical model of dynamic characteristics

A validated mathematical model of dynamic characteristics shall be used for new OHW system designs, where previous modelling is not available.

The dynamic performance shall be demonstrated using pantograph models supplied by the pantograph manufacturer.

Simulation programs, if used, shall be validated in accordance with EN 50318. The measurements on the installed contact wire shall be undertaken in accordance with EN 50317.

The assessment of the contact wire shall take into account trains with multiple pantographs. The performance of each pantograph, both separately and with the pantographs used collectively, shall be assessed.

Interaction between each pantograph and the OHW shall comply with the technical criteria given in I.S. EN 50367:2020.

6.4.4 Skew of the pantograph head

The OHW shall be designed to address the effect of the skew of the pantograph at locations of converging and diverging wires. In the case of pantographs with independent head springing, the additional head encroachment associated with independent pantograph head springing shall be addressed.

Encroachment, as defined in I.S. EN 50367:2020, is the perpendicular distance from the contact plane to the highest point of the pantograph head and is depicted in Figure 1. Encroachment shall not exceed 60mm from the contact point to the highest point on the conductor strip.

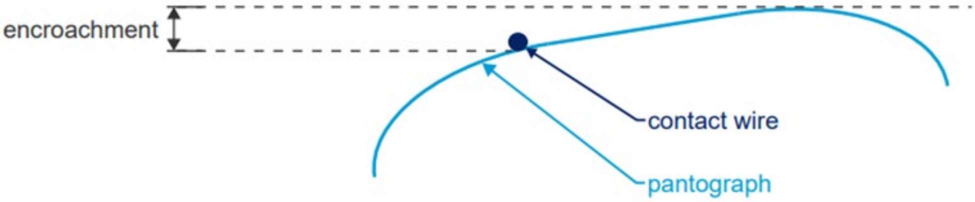

Figure 1 – Pantograph with independent head springing – encroachment

6.4.5 Wave propagation

Waves caused by pantograph forces on the tensioned contact wire(s) have a propagation velocity. The flexible overhead contact wire shall be designed so that the maximum operational speed of the line is less than 70% of the wave propagation velocity (v_c) of the contact wire.

The wave propagation velocity for flexible contact wire shall be calculated in accordance with I.S. EN 50119:2020, Clause 5.2.4.

6.4.6 Vertical movement of the contact point

For flexible OHW, space for free and unrestricted uplift at the support is required and shall be a minimum of 2 x S_0 (where S_0 is the design uplift of the contact wire).

If restrictions to uplift of the contact wire are included in the design, a figure of not less than 1.5 x S_0 shall be used.

6.4.7 Rigid overhead wiring maximum span length

Rigid OHW maximum span length shall be validated with dynamic simulation to demonstrate that the current collection requirement detailed in Section 6.4.2 is achieved.

6.5 Reliability, availability, maintainability and safety

The OHW shall be designed and configured to achieve the desired level of RAMS set by project System Requirements Specification. The OHW design shall offer a cost-effective solution while meeting the required RAMS target.

The OHW design shall address equipment as well as system failure modes. The RAMS of the system shall be demonstrated through simulation or practical experience from other railways, or both.

Factors of safety for mechanical loading for all conductors shall be in accordance with I.S. EN 50119:2020.

The OHW equipment shall have high proven reliability, requiring minimum or no maintenance. Where practical, equipment and associated components shall be items commonly used, readily available and interchangeable.

The OHW shall be configured to minimise service interruptions caused by maintenance. Where available, the design shall be informed by data on historic maintenance issues and risks.

The OHW design shall mitigate against bi-metallic corrosion between dissimilar materials.

The OHW shall be designed for bi-directional operation on the same track.

7 Overhead wiring system characteristics

7.1 Contact wire design

The contact wire shall be copper or copper alloy, as set out in EN 50149:2012, Clause 4.2.

Cadmium copper shall not be used.

The mechanical design of contact wire loads shall be in accordance with I.S. EN 50119:2020, Clause 5.3.

7.2 Catenary wire design

For contact and catenary AT systems, the catenary wire shall be hard-drawn stranded copper in accordance with AS 1746, or a stranded bronze wire in accordance with DIN 48201–2.

The mechanical design of catenary wire loads shall be in accordance with I.S. EN 50119:2020, Clause 5.4.

8 Overhead wiring system dimensional criteria

8.1 General

The OHW dimensional criteria and tolerances shall be complied with by all projects.

Criteria and tolerances to be agreed include, but are not limited to:

- future track lifting allowance
- track tolerances
- local track fixity
- OHW maintenance and installation tolerances
- sag due to ice
- pre-sag
- wire gradient
- rules for discrete features, such as turnouts or section insulators
- agreed deviations from the system design.

8.2 Normal minimum contact wire height

The normal minimum contact wire height should be the height of rolling stock plus electrical clearances plus tolerances, with special consideration for level crossings. Minimum contact wire height shall comply with I.S. EN 50119:2020.

8.3 Maximum contact wire height

Maximum contact wire height shall comply with I.S. EN 50119:2020 and I.S. EN 50367:2020.

8.4 Contact wire height at level crossings

The contact wire height used at level crossings shall be accepted by the rail authority and road authority.

8.5 Span length

The span length between consecutive support points is determined by track geometry, maximum allowed lateral deviation (blowout and stagger), wind loads and system parameters, e.g. contact line tension, temperature, maximum sag, and tolerances. Span length and design parameter shall comply with I.S. EN 50119:2020.

8.6 Wire run length

The maximum wire run length shall be calculated based on the maximum values for thermal expansion and contraction of the wires, along-track movement, tensioning system travel, tension loss, differential along-track movement, and stagger change.

Tension lengths with in-feeds shall address the higher temperature caused by current flow close to a feeder station.

At the midpoint of a full AT tension length, a restraint shall prevent along-track movement of the tension length.

8.7 Contact wire profile

The contact wire shall be designed in such a way that the vertical height of the contact point above the track is as uniform as possible along the span length. This is essential for high-quality current collection.

If a variation in contact wire height is required, this shall be achieved with as small a gradient as possible.

The maximum design values for gradient and changes of gradient of flexible overhead contact wire shall be in accordance with I.S. EN 50119:2020 and is set out in Table 3.

Table 3 – Recommended contact wire gradients for flexible overhead contact wire

Line speed up to (km/h)	Gradient		Change of gradient	
		%		%
10	1/17	60	1/33	30
30	1/25	40	1/50	20
50	1/40	25	1/80	12.5
60	1/50	20	1/100	10
100	1/167	6	1/333	3
120	1/250	4	1/500	2
160	1/300	3.3	1/600	1.7

For speeds that fall between the values in Table 3, the gradient and change of gradient can be calculated by linear interpolation.

Where practicable, a level span shall be provided between changes of direction of contact wire gradient.

For contact and catenary AT systems, the contact wire shall be profiled so that the total vertical load on all droppers acts downwards.

8.8 Catenary wire profile

For contact and catenary AT systems, the catenary wire shall be profiled so that the total vertical catenary load on all support structures acts downwards.

The catenary wire shall not be routed over the boom of new portal or TTC structures.

8.9 Stagger and deviation

8.9.1 Stagger

Nominal stagger for tangent track shall consider pantograph security. Where ROCS is used, a lower nominal stagger may be specified by the equipment supplier.

Maximum stagger shall be 350mm.

Staggers shall be designed to provide compliance to mid-span offset and contact wire lateral deviation. Where existing structures are utilised, staggers shall be designed to minimise the mid-span offset, where practicable.

To minimise wear on the wire and pantograph, a stagger sweep rate of between 2.5mm and 20mm per metre of span shall be applied.

8.9.2 Lateral deviation (blow out)

The maximum lateral deviation of the contact wire shall consider all operating conditions, the contact wire shall be contained within the pantograph working width.

Tolerances of lateral deviation of the overhead contact wire shall be considered for determining the limit of dewirement in accordance with I.S. EN 50367 and I.S. EN 50119:2020.

9 Design interfaces

Sections 9.1 to 9.7 set out requirements for the design interface with interfacing disciplines.

9.1 Track

The OHW geometry shall be designed to be in line with the parameters of the track layout and alignment. The parameters to be addressed shall include, but are not limited to the following:

- track gradient profile and location of the route, including turnouts and transitions
- types of turnouts
- track gauge

- track design speed.

9.2 Electrical power system design

9.2.1 Traction feeding arrangement

The traction power feeding arrangement and traction return system shall be as set out in TS 00103.1.

9.2.2 Nominal voltage and frequency

The system voltage and frequency shall be as set out in TS 00103.1.

9.2.3 Short circuit current details

The short-circuit current details for the 25 kV ac system shall be in accordance with TS 00103.1.

9.3 Earthing and bonding

Earthing and bonding requirements shall be in accordance with TS 00103.2.

9.3.1 Contact wire zone and current collector zone

The method for determining the zones in which structures may accidentally be made live by coming into contact with a live, broken contact wire or an energised de-wired or broken pantograph and its fragments shall be in accordance with TS 00103.2.

9.4 Rolling stock

9.4.1 General

The OHW shall be designed to be compatible with the rolling stock that is to be deployed on the line. The speed and performance capability of this rolling stock shall be specified by the rolling stock design for each line (or route).

The vehicle characteristics of all vehicle types permitted to be used on the line shall be incorporated into the OHW system design.

9.4.2 Vehicle gauge and swept envelope

The OHW shall be compatible with all vehicle gauges authorised for operation on the route, with all component parts remaining clear of the vehicle gauge and swept envelope.

9.4.3 Number and spacing of pantographs

The OHW for individual schemes shall be designed to be compatible with the number and spacing of pantographs designed for each project.

9.4.4 Pantograph profile and geometry

The interface between the pantograph and contact wire shall be designed to minimise the wear of both sub-systems.

The OHW design shall be compatible with the pantograph profiles. These shall comply with I.S. EN 50367:2020 Figure A.6, where the pantograph profile set out is compatible with the route.

9.4.5 Contact strips

The OHW design shall be compatible with pantograph contact strips composed of plain carbon in accordance with I.S. EN 50367:2020, Section 6.3.

9.4.6 Lateral movement of the pantograph

The OHW shall be designed to accommodate the full range of movement of the pantograph gauge. The contact wire shall not encroach within 200 mm of the outer end of each pantograph horn, considering the sway of the pantograph, where OHW wires are not converging or diverging.

The maximum pantograph sway shall be determined based on the rolling stock characteristics, wind speed, cant deficiency and contact wire height.

9.4.7 Contact forces

The OHW shall be designed to work at the maximum permissible contact forces between the pantograph and the contact wire. In addition, the system shall achieve a positive contact force to minimise the loss of contact between the pantograph and the contact wire.

The contact forces for ac systems shall be as specified in I.S. EN 50367:2020 Table 6.

9.4.8 Along-track working width of the pantograph head

The OHW design shall incorporate the pantograph head along-track width. This will be between 200 mm and 450 mm.

9.4.9 Pantograph gauge

The OHW design shall use a swayed and uplifted pantograph gauge which incorporates parameters including, but not limited to the following:

- uplift
- pantograph wear
- wire wear
- OHW tolerance
- track tolerance
- pantograph sway
- encroachment.

Nominal values for the above parameters are given in Table 4 and Table 5 The values used for individual projects and lines shall be coordinated with other interfacing disciplines identified in Sections 9.1 to 9.7.

Table 4 – Nominal parameters for flexible overhead contact wire

Parameter	Nominal values for flexible OH contact wire
Maximum uplift	250 mm
Pantograph wear	15 mm
Wire wear	dependent on wire type and tension
OHW tolerance	±20 mm
Track tolerance	dependent on track form type
Pantograph sway	dependent on rolling stock subject to wind speed and cant deficiency
Encroachment	≤60 mm

Table 5 – Nominal parameters for rigid overhead conductor lines

Parameter	Nominal values for rigid OH contact wire
Maximum uplift	0 mm
Pantograph wear	15 mm
Wire wear	dependent on wire type
OHW tolerance	dependent on the system and installation
Track tolerance	dependent on track form type
Pantograph sway	dependent on rolling stock subject to wind speed and cant deficiency
Encroachment	≤60 mm

9.5 Overline structures

OHW design at overline structures shall provide required clearances in accordance with Table 7.

OHW design at overline structures is preferred to be unattached to the overline structure. Attaching to structure is the least preferred option unless it is not practicable to design it unattached.

9.6 Signalling

Where reasonably practicable, structures and tie foundations shall be designed to be not less than 5m from signals, block markers or lineside signage.

Structures shall be positioned such that they do not obstruct the driver's view of signals, block markers or lineside signage.

Insulated overlaps shall not be positioned on the approach to train stopping points to prevent the pantograph(s) bridging an insulated overlap.

9.7 Overhead power lines

For routes where there are third-party HV power lines crossing the 25 kV ac OH contact wire, the clearance to the power lines shall be confirmed with the third-party supplier and comply with AS/NZS 7000 and AMB standards.

10 Typical design outputs and deliverables

System designs shall be developed. They may include conductor particulars, assembly general arrangement drawings, and assembly drawings. The system design shall define the range of working loads of all components and assemblies.

Project design deliverables shall be determined by the project. A non-exhaustive list of deliverables are outlined in Table 6.

Table 6 – Project design outputs and deliverables

Deliverable	Description
OHW layout plans	Identify new, modified, redundant and future installations as part of the proposed scheme. Staged drawings to be submitted as required. Note: For complex areas, the plans shall be drawn on a scale of 1:500 and for open route 1:1250.

Deliverable	**Description**
OHW cross sections and allocation schedules	As a minimum, OHW cross sections are for: • complex areas where a 1:500 layout plan is produced; • discrete features; • new structures. Allocation schedules accompanied by a generic cross section are acceptable for simple open-route areas where the project design is repetitive. Staged revisions to be submitted as required.
Section diagrams	For schemes introducing a new electrification system or amending the existing electrical sectioning on an existing electrified area.
Bonding plan	Record where structures are bonded to the track.
Wire-run schematic	Recommended for schemes in complex areas to accompany the 1:500 layout plan.
Schedule of limited clearances	Provide details of limited clearance locations, such as overbridges, tunnels, station platforms, signal gantries, where applicable, and the design clearance and any risk mitigation.
Foundation schedule	Provide details of new and existing OHW foundations.
Droppers table	Provide details of droppers within a contact and catenary system.
Structural calculations	Structural loading calculations, verified in accordance with I.S. EN 50119:2020, Section 6.2, AS/NZS 1170.1:2002 and AS/NZS 1170.2:2021.
Design report	Detail the OHW design methodology and notable features of the OHW design. May include any of the above deliverables. May also include, but is not limited to, the following additional information: • design log • designer’s risk assessment

11 Layout design

11.1 Layout design principles

11.1.1 General

OHW designs shall address how the works can be constructed and maintained.

Where flexible OHW is proposed, each tension length shall be mechanically independent.

SFAIRP, the designer shall minimise the extent to which the live equipment extends beyond the area directly above the running rails of the line to which it relates.

Live equipment shall be no closer than 3.5m from the land boundary.

11.1.2 Layout symbology

Design drawings should include a key to detail the symbology deployed.

11.1.3 New layout designs

Requirements for overlaps and MPAs shall be determined based on the maximum half tension length of the system in conjunction with the requirements of the feeding and sectioning arrangements.

The layout design of OHW shall address all of the following:

- establish the position of feeding and sectioning points
- establish positions of overlaps
- establish the wire run lengths
- establish the position of signals, block marker signs and lineside signage
- establish structure types and spacing, considering design wind speed and track curvature data
- determine staggers, considering stagger change due to along-track movement
- determine if the along-track drag (restoring forces) effects are likely to be relevant – calculate if required
- determine the wiring arrangements at crossovers, turnouts, junctions, and bridges
- address electrical clearances from adjacent tracks, for example at a crossover
- allow 3m of clearance, where practicable, between adjacent sections for safety of the Asset Steward – operate or maintain. For cantilevers placed between lines of two different electrical sections, stagger structures up to 10m along-track as required
- determine contact wire heights and system heights
- address special features such as stations, overbridges, and tunnels, which may have specific electrical clearance requirements
- if applicable, determine the positions of any OHEWs, and RSCs, in conjunction with bonding design to determine the locations of switches and SIs.

Wire run lengths shall include a tolerance for overlap and mid-point anchor positions to mitigate against major re-design works should a single overlap be relocated.

Overlaps shall be positioned to achieve the optimum wire length in accordance with Section 8.6.

11.1.4 Upgrade or modification

When upgrading or modifying existing 25 kV ac infrastructure, designs for existing structures and OHW that are impacted shall be re-evaluated for parameters such as loading. Existing structures and OHW that are impacted shall be upgraded to remove existing non-compliances.

11.1.5 Layout plan simplification

The layout of OHW equipment shall be simplified and laid out to minimise the number of OHW support structures, SFAIRP. Examples of instances where simplification opportunities may be identified include but are not limited to:

- placing anchors in two or multi-track areas at one location
- selection of structure positions for optimum use.

Potential savings from simplification shall be balanced against safety and whole of life costs.

11.2 Structure positioning

11.2.1 General

No part of OHW electrical support structure shall impede on the structure gauge. New structures shall be positioned such that they provide enough clearance to the kinematic envelope of the rolling stock and shall not be on access road. Visibility of signals, block markers and lineside signage shall be assessed when positioning new structures.

Structures near roads and rail-road access points shall be positioned to minimise the risk of road vehicle impact.

When structures are positioned where there is a risk of road vehicle impact, then the need for crash protection measures, such as crash barriers, shall be addressed.

All structure locations shall be risk assessed for fitting of anti-climb guards. Structure should be at least 3m from closest edge of culvert.

OHW structure shall be determined by the OHW electrical design engineer and then agreed with the signal design engineer and the civil design engineer. Signal gantry position shall be determined by the signal design engineer and then agreed with the civil design engineer.

11.2.2 Structure spacing

Structures shall be spaced in the most economic manner practicable.

The maximum individual span shall take into account the proposed OHW ‘system type’, track geometry, tolerances, wind speed, wire geometry, minimum dropper length and temperature range.

11.2.3 Structure positioning tolerance

An along-track and across-track allowance of ± 50mm shall be applied to the design mast positions for construction tolerance.

For portal structures, the combined tolerance across all foundation positions and tolerance of cantilever and portal arms where electrical fittings attach shall comply with the construction tolerance allowance and calculations in I.S. EN 50119 and I.S. EN 50367.

11.2.4 Prohibited structure positions

Structures shall not be situated in the path of catch points.

Placing new structures outside the rail corridor boundary shall be avoided SFAIRP. No live equipment shall be within 3.5m of the land boundary.

Placing new structures on platforms shall be avoided, SFAIRP.

Where a structure is required on a platform, the minimum clearance from platform edge to face of steel shall be 2.5 m.

11.3 Overlaps

The design of overlaps shall enable pantographs to pass from one tension length or conductor bar section to the next without interruption of the traction power supply.

Where overlaps are used as sectioning points then insulated overlaps shall be provided. At insulated overlaps minimum static and passing clearances shall be achieved between live parts of different electrical sections or sub-sections.

SFAIRP, all overlaps shall be designed to the standard dimensions of an insulated overlap to allow passive provision for future conversion of uninsulated to insulated overlaps.

Uninsulated overlaps shall be permanently connected with jumpers. Insulated overlaps shall be connected via disconnectors.

For flexible OHW, overlap types shall be chosen based on location-specific requirements. In general, the order of preference for selection of overlap type is:

1. three-span overlap
2. single span overlap
3. two-span overlap (single point overlap) – allowable only in low-speed areas.

11.4 Terminations

For flexible OHW, terminations shall be AT anchors. The order of preference for the selection of tensioning equipment shall be:

1. constant stiffness spring tension anchor
2. balance weight anchor with anti-fall devices.

Gas or variable stiffness spring tensioning equipment shall not be used.

On terminal lines and sidings, the termination insulation shall be positioned before the buffer stop, such that the live equipment does not extend beyond the running line.

Anchor heights shall be defined by the height of the in-running contact wire height.

For rigid OHW, due to the continuous support of the contact wire provided by the aluminium conductor bar, it is not necessary to apply mechanical tension to the contact wire and tensioning equipment may be omitted.

11.5 Turnouts

11.5.1 General

The OHW above turnouts shall be designed to be suitable for trains travelling in all directions at the operating speed.

Turnouts may be wired tangentially or with cross contacts.

Where practicable, along-track movement shall be in the same direction for all wires at the turnout structure. Wires moving along-track in the opposite direction shall only be designed in exceptional circumstances.

Multiple crossovers shall be independently wired, with one wire per crossover. A single wire may run over two crossovers, provided the crossovers are between the same lines.

Full current carrying jumpers shall be allocated between mainline and turnout wire runs.

For ROCS systems, turnouts shall be wired in accordance with system manufacturer’s requirements.

11.5.2 Gradients and track level difference

Wires on all tracks affected by the crossover shall, SFAIRP, be graded such that they are coplanar at the crossover and turnout location.

11.5.3 Wiring arrangement

The conductors shall be arranged to ensure that no equipment can be trapped below the pantograph head.

The designer shall check minimum staggers to ensure there are no clashes between main line and crossover wiring arrangements.

At all turnouts, regardless of whether they are wired with cross contacts (as shown in Figure 3), tangential or open, the conductor geometry shall be assessed to ensure compliance with the following:

- registration arms, jumpers, splices and insulators shall be located outside of the fitting free area, as shown in Figure 2
- throughout contact wire run-up and run-down areas, both contact wires (including at maximum blow-off) shall be placed between the two track centrelines, as shown in Figure 3
- the turnout wire shall be level with the mainline wire at the point where the mainline and turnout wire are 500mm apart horizontally
- the turnout wire shall be nominally 20mm above the mainline wire at the support and at the cross-contact location
- the radial loads on the registrations shall be within the working range of equipment design at any specific location
- maximum lateral deviation shall be as specified in Section 8.9.2
- catenary wires shall maintain a 25mm minimum separation under all conditions
- cross contact bars or cross droppers shall be provided as required.

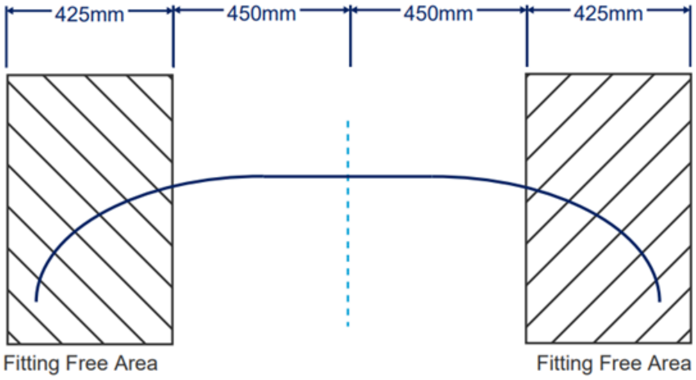

Figure 2 – Fitting free area

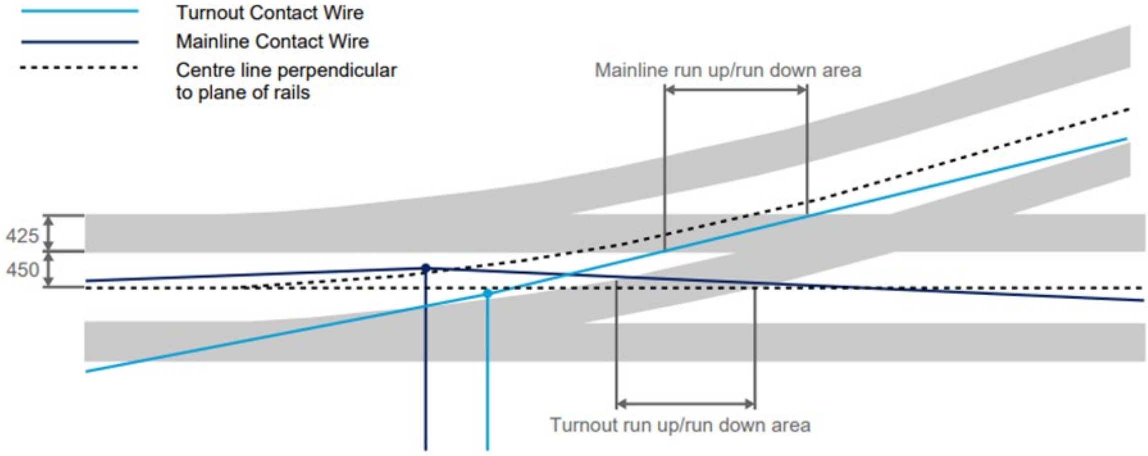

Figure 3 – Turnouts wired with cross contacts (plan view)

12 Structure design

12.1 General

OHW support structures shall be hot-dip galvanised steel in accordance with AS/NZS 4680.

The use of back-to-back cantilevers on a single mast should be avoided where the contact wire on either side of the mast belong to separate electrical sections or sub-sections.

Where required, installation rake for support structures shall be identified at the detailed design stage.

Headspan type structures shall not be used because the lack of mechanical independence between different sets of OHW adversely impacts reliability and availability.

12.2 Tunnel areas

In tunnel areas, the OHW shall be supported from tunnel soffits and walls as appropriate. SFAIRP, supports shall be attached to the tunnel at precast fixing points to reduce the volume of onsite drilling required.

12.3 Open areas

12.3.1 Single and two track areas

SFAIRP, the support and registration equipment should be attached to STC masts. The order of preference for selection of structures type shall be:

1. portal
2. STC

3. TTC.

12.3.2 Multi-track areas

For multi-track areas, the use of STCs should be optimised where possible. However, cost savings may be realised in multi-track areas by the use of multi-track structures. Structures shall be allocated in the following order of preference:

1. STC
2. TTC
3. portal.

12.3.3 Anchor structures

The following types of structures may be used to anchor flexible OHW (selected by merit, on a case-by-case basis):

- FSAM
- back-tie anchor, affixed to the mast of an STC, TTC or portal
- anchor portals.

12.4 Cantilever design

The cantilevers shall be hinged around the vertical axis to allow for the along-track movement of AT equipment within the allowed limits.

12.5 Registration arm selection

The selected registration arm shall achieve the required stagger without infringing on the pantograph mechanical clearance envelope.

SFAIRP, the shortest registration arm shall be selected.

Under all conditions, a mechanical clearance of 80mm shall be applied from the pantograph to the heel of the registration arm.

12.6 Knuckles

Knuckles shall only be used where the differential along-track movement of equipment is less than 40mm per 300mm length of knuckle.

Knuckles shall be a minimum of 1m in the along-track direction from adjacent steady arms.

12.7 Structural loading

Structural loading shall be verified in accordance with I.S. EN 50119:2020, Section 6.2, AS/NZS 1170.1 and AS/NZS 1170.2.

12.8 Foundations

OHW foundations shall be designed in accordance with AS 3600, AS 2159 and I.S. EN 50119:2020 Sections 6.5.2 to 6.5.12.

12.9 Attachment to civil assets

The mechanical integrity of the connection to the civil structure and the effect of the loading from the OHW on the civil structure shall be assessed and verified by asset's steward – operate or maintain as acceptable.

12.10 Structure numbering

All OHW structures shall have a unique identification number.

Structure numbers shall be an alphanumeric code in the following format:

- X YY+ZZZ

where:

- X is the prefix of one to three letters, which denotes the line on which the OHW is located and is assigned by AMB
- YY is the distance given in km within that route from a specified reference location
- ZZZ is the meterage within that km, given as three digits.

For example, 'SW 13+351' denotes that the structure is on the Illawarra Line and located at a nominal distance of 13.351 km from the reference location.

13 Sectioning

13.1 General

Electrical sectioning points shall be positioned as per the SLD.

Electrical sectioning locations shall be coordinated with the UTO system. The UTO system shall prevent trains from entering isolated sections and earthed sections.

OHW sectioning shall be facilitated by TSCs and the switching requirements specified in TS 00103.1.

Insulated overlaps shall be used in main running lines for sectioning, where practicable.

The designer shall not locate insulated overlaps where train pantographs are calculated to come to a standstill.

The OHW shall be electrically sectioned as required to support the operational and maintenance requirements for each line.

Each electrical section and sub-section shall be provided with earthing facilities as per TS 00103.2.

Electrical sectioning shall be provided at the departure end of station platforms and crossovers, considering the intended direction of operation of the track under normal operating conditions.

13.2 Insulated overlaps (sectionable overlaps)

Insulated overlaps should be used to provide sectioning points on mainlines with contact and catenary AT equipment.

At insulated overlaps, minimum static and passing clearances shall be achieved between live parts of different electrical sections or sub-sections.

13.3 Section insulators

SIs should be avoided in contact and catenary AT systems for sectioning on mainlines. SIs may be used on crossovers and in areas where it is not possible to fit insulated overlaps.

Notes:

1. For contact and catenary AT systems, additional structures may be required to register the contact wire in order to maximise the system height at an SI location, to maintain the required SI offset to the track centreline, and to stabilise the SI on long spans and improve performance.
2. For contact and catenary AT systems, the system height required for section insulators depends on the type installed.

Section insulators shall be designed in accordance with manufacturer’s requirements.

The offset to the track centreline shall be limited so that the section insulator remains within the working width of the pantograph under worst case conditions of blow-out and track tolerances.

If the contact wire is registered, the registration assembly shall be positioned adjacent to the main line wire run in the same electrical section, staggered along-track relative to the opposite structure to improve electrical clearance.

13.4 Switches and disconnectors

Switches and disconnectors shall be supplied in accordance with EN 50152–2.

13.4.1 Disconnectors (isolating switches)

Disconnectors shall not be used for remote sectioning or reconfiguring and are not rated for opening on-load.

13.4.2 Switch disconnectors

The electrical sectioning shall be developed to incorporate the following principles:

- sectioning switches shall be combined with the TSCs, where possible
- all switch disconnectors shall be three-position combined fault break, load break and earthing switch
- all switch disconnectors shall be remotely controlled via the SCADA system and provided with local key controlled manual override, for use in case of SCADA failure
- earth positions shall be provided to allow for the remote earthing of the OHW and facilitate safer and faster isolations for maintenance
- the switch disconnectors shall provide the means for remote securing when in the earth position.

13.5 Fixed earthing devices

To facilitate the emergency scenarios inside tunnels, FEDs may be installed for connecting a de-energised OHW section to earth potential.

14 Infrastructure clearances

14.1 Live to earth

Clearances between live parts of the OHW and earth are defined to limit damage to the OHW or earthed infrastructure and to protect public and workforce safety.

To achieve this, the OHW shall be designed to provide a minimum of functional insulation in accordance with EN 50124–1 and I.S. EN 50119:2020.

Functional insulation requirements are dependent upon Rated Impulse Voltage, U_{Ni}, determined for the system. For infrastructure, this is dependent upon transient overvoltage conditions that include short duration transients. The Rated Impulse Voltage is based upon environmental conditions (for example lightning strikes) and protective or inherent control.

Different clearances for static and dynamic cases are justifiable by probabilistic determinations considering duration of the fault. For example, it is improbable that an over-voltage surge will occur at the same moment that a pantograph passes a narrow part of a tunnel. For this "dynamic" or temporary case, the use of a dynamic clearance is justified.

The OHW shall be designed to provide electrical clearances greater than the normal minimum clearances detailed in Table 7

Table 7 – Normal minimum live to earth infrastructure clearances

Nominal Voltage, U_n	25 kV ac
Rated Insulation Voltage, U_{Nm}	27.5 kV ac
Rated Impulse Voltage, U_{Ni}	200 kV ac
Normal Minimum Static Clearance	270 mm
Normal Minimum Passing Clearance $^{\text{NOTE 1}}$	150 mm

Note 1: The normal minimum passing clearance applies after uplift and other tolerances have been taken into account.

For catenary wires where live to earth clearances are less than 500 mm, solid contenary wire shall be installed in place of the stranded wire.

Note: this requirement does not apply between electrical sections and sub-sections at insulated overlap locations.

A twin contact arrangement is permissible where required to reduce the system height to zero to achieve clearances to lower height overline structures. Where required, the second contact wire will be spliced into the catenary either side of the structure.

Where it is not reasonably practicable to achieve the clearances detailed in Table 7, then by limiting the over-voltage via surge arrestors, the clearance dimensions may be reduced to below the normal minimum values given.

14.2 Mechanical clearances

The minimum mechanical clearances to overhead contact wiring equipment shall be in line with Table 8 and Table 9.

Table 8 – Mechanical clearance between pantographs and live overhead line equipment

Overhead line equipment	Minimum static and passing mechanical clearance to the pantograph gauge
Between swayed and uplifted pantographs and contact wiring equipment at the same electrical potential	80 mm

Overhead line equipment	Minimum static and passing mechanical clearance to the pantograph gauge
Between swayed and uplifted pantographs and steady arms, when uplifted and approximately parallel to the pantograph profile.	15 mm (see note)

Note: Under all conditions, including wear of the contact wire and pantograph.

Table 9 – Mechanical clearance to earthed contact wires

Overhead line equipment	Minimum static and passing mechanical clearance to the swept envelope height of the rolling stock
Earthed contact wire	50 mm

15 Electrical safety

At all authorised places of direct public or staff access to electrified lines or electrical equipment locations and enclosures, signs giving suitable warning of the dangers from live electrical equipment shall be displayed.

Overhead equipment structures and supports shall be of a design, which cannot easily be climbed. Where this is not achieved and there is public access to the structure or trespass is likely, anti-climbing protection shall be provided.

15.1 Protection by clearance

Bare live equipment associated with OHW System shall be kept to a minimum and shall be sited to minimise danger. Live equipment shall not extend over non-electrified lines, behind any buffer stop, over the platforms or any other public part of a station.

Wherever practicable, the designer shall provide protection against direct contact by clearance, in accordance with EN 50122–1:2022, Clause 5.2.

When modifying, renewing or installing new railway subsystems that affect the clearance from the OHW or live parts of the pantographs to a standing surface, the design of the subsystems shall maximise the clearance SFAIRP.

The electrical clearances shall be assessed from a standing surface to the exposed live parts of the OHW and exposed live parts mounted on vehicles.

15.2 Protection by electrically protective obstacles

Where the protection by clearance cannot be achieved, protection by electrically protective obstacles shall be provided in accordance with EN 50122–1:2022, Clause 5.4.

Appendix A Sample design

A.1 Introduction

This sample design is provided for information only and is intended to highlight some of the key characteristics required for a 25 kV OHW system design and to provide indicative guidance on how the technical requirements contained within the 25 kV ac OHW system standard may be met.

A.2 Design key items

The following is a list of key items that are required to be selected, worked out or considered in design development of a 25 kV ac OHW system:

- system type
- contact wire height
- contact wire grading
- design life
- construction tolerances
- contact wire height and grading
- electrical sectioning arrangement
- foundations
- conductor type and tension
- termination anchor
- tension length configuration
- span length configuration
- stagger.

The following sections elaborate on each item for fixed OHW and ROCS.

A.3 General design items

A.3.1.1 Construction tolerances

The construction tolerances of the OHW equipment, used in design, are shown in Table 10.

Table 10 – OHW construction tolerances

Parameter	Tolerance
Contact wire heights: • Flexible OHW • ROCS	 +/– 75 mm +/– 10 mm
System height	+/– 25 mm
Dropper lengths	+/– 5 mm
Stagger	+/– 25 mm
Registration setting along-track	+/– 50 mm

A.3.2 Electrical sectioning arrangements

A.3.2.1 Insulated overlaps

Sectioning and sub-sectioning will be provided with insulated overlaps. It is envisaged that insulated overlaps will be identical to mechanical overlaps, but with the addition of insulation to electrically separate the OHW system conductors on either side. Switches will be provided where necessary to allow for the electrical connection of the two OHW sub-sections when required.

A.3.2.2 Section insulators

In areas where it is not possible to physically locate an insulated overlap, then the sectioning can be achieved by installation of section insulators.

A.3.3 Foundations

Foundations will consist of circular hollow section piles or cast in situ reinforced concrete. The OHW may also be supported directly from civil structures, such as overbridges or tunnel soffits.

The foundations are critical elements of the OHW and predicted loading from the OHW equipment is required to provide an economical design. This loading is developed based on:

- OHW configuration, for example wire sizes and type of construction
- climatic conditions, for example wind loading and temperature variations
- applicable factors of safety.

There are also areas where the loading is required to enable the civil design elements to be developed, such as viaducts and bridges.

A.4 Flexible overhead wiring specific design items

A.4.1 Conductor types and tensions

The OHW conductor sizes will be based on the electrical and mechanical requirements of the system. For flexible OHW systems, the conductor particulars are outlined in Table 11.

Table 11 – Flexible OHW conductor particulars

Conductor type	Conductor size	Tension
Contact wire	107 mm² hard drawn copper or copper alloy	Tension of 11 kN
Catenary wire	19/2.1mm stranded BzII	Tension of 11 kN
Earth wire	19/3.25mm stranded aluminium with fixed terminations	Tensioned so that the maximum tension, which occurs at the minimum temperature, is less than the rated working tension of the wires including appropriate safety factors.

A.4.2 Termination anchors

For flexible overhead wiring systems, the contact wires and catenary wires will be automatically tensioned such that the tension in the conductors remains constant at all temperatures within the operating range.

It is proposed that the tensioning devices will be either constant stiffness spring tensioning anchors or balance weight anchors, the former being the preferred tensioning device.

The OHEW will be installed with fixed termination anchors.

It is proposed that all OHW anchor structures in areas such as stations and maintenance facilities are FSAM. Elsewhere, anchors may be provided with back-ties or struts.

Termination anchors may also be provided to terminate the OHW wiring where there is a transition section between OHW and ROCS.

A.4.3 Typical tension length configuration

For flexible OHW configurations (such as simple catenary and trolley wire systems), the OHW is split into individual tensioning sections called tension lengths. Figure 4 shows a typical tension length configuration.

Figure 4 – Schematic showing typical tension length configuration for flexible OHW

A tension length runs between the termination anchors at either end of the section of OHW. A mid-point anchor is provided approximately half-way along each tension length to restrain the conductor from migrating from one termination anchor to the other, also to limit damage to the OHW in the event of a conductor failure.

The maximum tension length for any given tension length installed will be determined based on along-track movement, stagger change and tension loss. Indicative maximum tension lengths applicable to each termination anchor type are shown in Table 12.

Table 12 – Maximum tension lengths (OHW)

Termination anchor type	Maximum half tension length (m)	Maximum tension length (m)
Constant stiffness spring tensioning anchors	800	1600
Balance weight anchors	985	1970

At the interface between a tension length and an adjacent tension length, an overlap is provided to ensure trains can pass between tension lengths with no interruption of power supply.

A.4.4 Typical span length configuration

For contact and catenary systems, the contact wire is supported from the catenary wire by droppers, as shown in Figure 5. It is proposed to space the droppers at a maximum of 10m spacing.

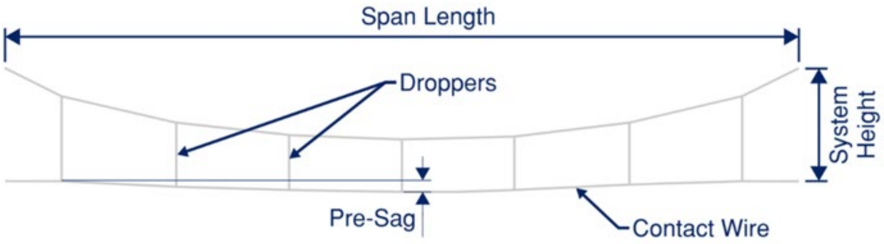

Figure 5 – Typical span configuration for contact and catenary system

In a typical span, the contact wire is not level to the track throughout the span but is intentionally sagged throughout the span length. This sag is referred to as pre-sag. Pre-sag will have a nominal value of one-thousandth of a span length.

For trolley wire systems, shown in Figure 6, the contact wire is suspended from a bridle, which is interposed between the support and the contact wire. The contact wire sags under its own weight between supports.

Figure 6 – Typical span configuration for trolley wire system

Span lengths should be maximised to reduce the number of supporting structures required. For flexible OHW, normal maximum span lengths are defined in Table 13.

Table 13 – Normal maximum span lengths for OHW

System type	Normal maximum span length
Contact and catenary system	up to 75m
Trolley wire system	up to 45m

Note: The actual maximum span length for any given location in a OHW system will be limited by the width of the pantograph, the curvature of the track, the wind loading and other structure positioning constraints.

A.4.5 Stagger

To provide even wear over the pantograph carbons, the contact wire shall be staggered. The maximum values shall be determined from a pantograph analysis. Normal maximum stagger values for flexible overhead wiring systems are outlined in Table 14. It is proposed that the design of stagger and offset of the contact wire be such that the contact wire does not encroach beyond the outside 200mm of the pantograph under all operating conditions.

Where fitted, the catenary wire is proposed to be positioned directly above the contact wire.

Table 14 – Normal maximum staggers for OHW

System type	Maximum stagger (mm)
Contact and catenary system	350
Trolley wire system	350

A.5 Rigid overhead conductor system specific design items

A.5.1 Conductor types

The OHW conductor sizes will be based on the traction power requirements for the system. For ROCS, the conductor particulars are outlined in Table 15.

Table 15 – ROCS conductor particulars

Conductor type	Conductor size	Tension
Conductor bar	Aluminium extruded section with 107mm^2 hard drawn copper or copper alloy contact wire	Non-tensioned

A.5.2 Typical tension length configuration

For rigid OHW, the OHW is split into individual sections called tension lengths. Figure 7 shows typical tension length configurations.

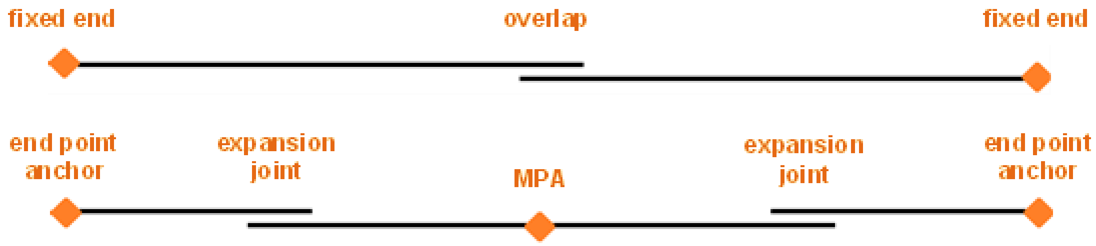

Figure 7 – Schematic showing typical tension length configurations for rigid ROCS

An expansion joint or expansion overlap is included at either end of a tension length to control the expansion and contraction of the conductor rail due to the temperature variation.

A mid-point anchor is provided approximately half-way along non-tensioned length, to restrict the along-track movement of the contact wire.

The maximum length of each tension length is limited by the along-track expansion with temperature and will typically be 600 m.

A.5.3 Typical span length configuration

In a typical span, the contact wire and aluminium beam are not level throughout the span and sag under their own weight between supports. As span lengths increase, the sag increases. This sag defines the maximum operational speed of the system. For a higher speed system, shorter span lengths with less sag are required.

Span lengths should be maximised to reduce the number of supporting structures required. For ROCS, normal maximum span lengths are defined in Table 16.

Table 16 – Normal maximum span lengths for ROCS

System type	Normal maximum span length
ROCS	8m to 12m (depending on line speed)

A.5.4 Stagger

To provide even wear over the pantograph carbons, the contact wire is to be staggered, as depicted in Figure 8.

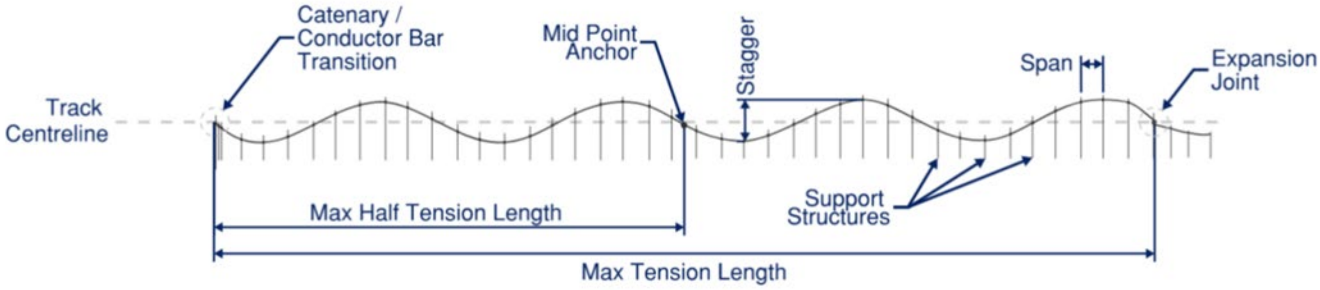

Figure 8 – Typical ROCS stagger profile (plan view)

The maximum values of the stagger shall be determined from a pantograph analysis. Normal maximum stagger values for ROCS are outlined in Table 17. It is proposed that the design of stagger and offset of the contact wire be such that the contact wire does not encroach beyond the outside 200 mm of the pantograph under all operating conditions.

Table 17 – Normal maximum staggers for ROCS

System type	Maximum stagger (mm)
ROCS	150

A.6 Comparative analysis

Table 18 provides an indicative comparison of ROCS and OHW and outlines some of the advantages and disadvantages of ROCS. This information is provided for guidance only. Designers should assess the merits of each system type for each project considering the project requirements.

Table 18 – Advantages and disadvantages of ROCS

Advantages	Disadvantages
Reduced pantograph uplift, even with multiple pantographs, can allow smaller tunnel cross-sections.	ROCS systems have been demonstrated to achieve required performance. However, the lack of elasticity means that construction tolerances are reduced and must be strictly implemented when compared to OHW.
Offers high current carrying capacity, so that additional feeders can be avoided.	Needs to be supported every 8 to 12m dependant on the profile and the speed; so additional supports are required to register the rigid beam. More expensive and takes longer to install.

Advantages	Disadvantages
Extreme operational reliability and requires reduced maintenance regardless of the operating voltage.	Due to size of insulator for 25 kV, limits its use where electrical headroom clearance is limited, particularly in round tunnel apertures.
Suitable for use for retractable OHW in depots.	Beams have to be pre-ordered for tight curves and there are long lead times, so spares need to be kept in stores in close proximity to site.
Improved mechanical performance in a fire situation.	Although this system requires reduced maintenance, the maintenance tolerances are tighter.
Transition section and anchors are required to transition from OHW to ROCS. Tensionless systems so no anchors required.	
Reduced risk of a broken live wire falling.	
The requirement for an overhead contact wire zone is removed.	
Less along-track distance required for overlap due to air gap design.	