Standard

1500 V DC Cables and Cable Ratings

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Standard governance

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

Document history

<table>
<thead>
<tr>
<th>Version</th>
<th>Summary of changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Initial release, 12 March 2014.</td>
</tr>
<tr>
<td>2.0</td>
<td>Second issue.</td>
</tr>
</tbody>
</table>
Preface

The Asset Standards Authority (ASA) is a key strategic branch of Transport for NSW (TfNSW). As the network design and standards authority for NSW Transport Assets, as specified in the ASA Charter, the ASA identifies, selects, develops, publishes, maintains and controls a suite of requirements documents on behalf of TfNSW, the asset owner.

The ASA deploys TfNSW requirements for asset and safety assurance by creating and managing TfNSW’s governance models, documents and processes. To achieve this, the ASA focuses on four primary tasks:

- publishing and managing TfNSW’s process and requirements documents including TfNSW plans, standards, manuals and guides
- deploying TfNSW's Authorised Engineering Organisation (AEO) framework
- continuously improving TfNSW’s Asset Management Framework
- collaborating with the Transport cluster and industry through open engagement

The AEO framework authorises engineering organisations to supply and provide asset related products and services to TfNSW. It works to assure the safety, quality and fitness for purpose of those products and services over the asset's whole-of-life. AEOs are expected to demonstrate how they have applied the requirements of ASA documents, including TfNSW plans, standards and guides, when delivering assets and related services for TfNSW.

Compliance with ASA requirements by itself is not sufficient to ensure satisfactory outcomes for NSW Transport Assets. The ASA expects that professional judgement be used by competent personnel when using ASA requirements to produce those outcomes.

About this document

This standard sets out the technical requirements for cables in the 1500 V dc traction system of the metropolitan rail area.

This is the second issue of this standard. The changes to previous content include the following:

- incorporation of the content of technical notes TN 087: 2014 and TN 063: 2015
- amendments to current ratings of cables in Appendix A
- Appendix B added to provide guidance on applying the requirement on 1500 V feeder ratings
- minor amendments and clarification to content
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1. **Introduction**

For practical reasons of commercial availability, most cables used in the 1500 V dc traction system of the metropolitan rail area are insulated to one of the standard alternating current (ac) voltages. The continuous current rating data from cable manufacturers are for three-phase alternating currents, and are generally not applicable to cables carrying direct currents with cyclic loading conditions.

2. **Purpose**

This document sets out the technical requirements for cables in the 1500 V dc traction system of the metropolitan rail area, along with the requirements under which ac cables and other cables are used in the 1500 V dc traction system.

2.1. **Scope**

This document includes the typical loading conditions and current carrying capacity requirements for cables in the 1500 V dc traction system. Cables used for the interconnection and control of rectification equipment and interconnection of overhead wiring electrical sections are considered part of the 1500 V dc traction system.

Approved cable types and sizes are also detailed.

2.2. **Application**

This standard is applicable for all new cable installations, as well as alterations to existing installations, in the 1500 V dc traction system.

Cable types used in existing installations may be used for repairs to existing cables involving like-for-like replacements with the approval of the appropriate engineering authority of the relevant Authorised Engineering Organisation (AEO).

XLPE insulated cables in existing stock may continue to be used, provided that the cables comply with all other requirements of this standard.

3. **Reference documents**

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

**International standards**

IEC 60287 Electric cables – Calculation of the current rating
Australian standards

AS/NZS 1429.1 Electric cables – Polymeric insulated – For working voltages 1.9/3.3 (3.6) kV up to and including 19/33 (36) kV

AS 2067 Substations and high voltage installations exceeding 1 kV a.c.

AS/NZS 3008.1.1 Electrical installations – Selection of cables – Cables for alternating voltages up to and including 0.6/1 kV – Typical Australian installation conditions

AS 3569 Steel wire ropes – Product specification

AS/NZS 3808 Insulating and sheathing materials for electric cables

AS/NZS 5000.1 Electric cables – Polymeric insulated – For working voltages up to and including 0.6/1 (1.2) kV

Transport for NSW standards

EP 00 00 00 13 SP Electrical Power Equipment – Design Ranges of Ambient Conditions

EP 03 00 00 01 TI Rectifier Transformer and Rectifier Characteristics

EP 03 02 30 00 SP Semiconductor 12 Pulse Series Bridge Rectifier Power Cubicle

ESG 100 Signal Design Principles

SPG 1010 Cables for Railway Signalling Applications – General Requirements

SPG 1012 Cables for Railway Signalling Applications – Single and Twin Conductor Cables

SPG 1014 Cables for Railway Signalling Applications – Traction Return Bonding and Track Connection Cables

T HR EL 08010 ST Overhead Wiring Conductor System Selection

T HR EL 20001 ST High Voltage AC and 1500 V DC Traction Power Supply Cable Requirements

T HR EL 90003 ST Heavy Rail Traction System – Current Ratings of 1500 V dc Equipment

4. Terms and definitions

The following terms and definitions apply in this document:

AEO Authorised Engineering Organisation

ASA Asset Standards Authority

DCCB direct current circuit breaker

EPR refer to AS/NZS 3808 for the definition of EPR insulating material

OHW overhead wiring

PVC polyvinyl chloride
5. General requirements

Except where otherwise specified, cables shall be selected to comply with the requirements of AS 2067 Substations and high voltage installations exceeding 1 kV a.c. and AS/NZS 3008.1.1 Electrical installations – Selection of cables – Cables for alternating voltages up to and including 0.6/1 kV – Typical Australian installation conditions.

5.1. Unscreened cables

Unscreened cables may be used in the following situations:

- Cables at 1500 V negative potential.
- 1500 V positive cables within equipment that has been designed and tested to relevant standards.
- 1500 V positive cables located inside a traction substation where a risk assessment has determined that the risk of inadvertent contact with the cable is low. Warning signs shall be installed at all such locations.

5.2. Minimum two-cable situations

Where there is a reasonable likelihood that a cable termination may be disconnected through vandalism or maintenance and construction activities, and the disconnection may result in a hazardous situation for members of the public or maintenance workers, a minimum of two cables in parallel shall be provided for the cable connection.

The two cables in parallel shall be terminated independently.

6. Cyclic rating

The rectifiers in the 1500 V dc traction system are subject to daily cyclic loadings. For some cable connections, it is more appropriate to use a cyclic rating to determine the size and number of cables to be used.

The typical load cycle is representative of weekday loads in the inner metropolitan area and consists of morning and afternoon peaks of 100%, falling to 85% in the middle of the day and 35% overnight. The peak value is the root mean square (rms) of the values over the peak one hour. A typical load cycle is shown in Figure 1.
7. **Cable connections at substations**

Typical cable connections at traction substations are shown in Figure 2, Figure 3, and Figure 4.

The rail earth contactor (REC) may be connected directly to the control negative bus with a shared negative bus.

Typical connections at traction substations include the following:

- connections that are in series with a rectifier
- rectifier transformer to rectifier
- rectifier negative bus to main negative bus
- main negative bus to nearside trackside negative bus
- nearside trackside negative bus to farside trackside negative bus

Where different installation configurations are used, the requirements for cables of such installations shall be determined as part of the design process. For example, electrical equipment may be connected via busbars within a substation. In such configurations, the cables nominated in this document for connection between the equipment are not required.
Figure 2 - Typical transformer and rectifier arrangement

Figure 3 - Typical substation dc arrangement
7.1. Connections that are in series with a rectifier

The rectifiers in the 1500 V dc traction system have overload characteristics as set out in EP 03 02 30 00 SP Semiconductor 12 Pulse Series Bridge Rectifier Power Cubicle.

The typical rectifier weekday load profile in inner metropolitan area cyclic loading shown in Figure 1 allows for rectifier operation at a cycle peak of 150% of the rectifier continuous rating. Cables in series with the rectifier shall then have adequate capacity for the given cyclic load profile, and with a peak current of 150% of the rectifier continuous current rating.

For a typical substation dc arrangement, the cables that connect between the rectifier positive bus and the rectifier negative bus with one rectifier directly in series include the following:

- rectifier negative link to rectifier negative bus
- rectifier positive to direct current circuit breaker (DCCB)

Figure 5 shows a typical rectifier negative link to rectifier negative bus connection.
Figure 5 - Typical rectifier negative link to rectifier negative bus

Figure 6 shows a typical rectifier positive to DCCB connection.

Figure 6 - Typical rectifier positive to DCCB

Where the rectifier negative link is separate from the rectifier unit, the cables connecting them are also in series with the rectifier.

Table 1 lists the currents corresponding to 150% of continuous dc current rating for the range of rectifier ratings existing in the 1500 V dc traction system. The values in Table 1 are based on a rectifier full load output voltage of 1550 V dc.

<table>
<thead>
<tr>
<th>Rectifier continuous rating (MW)</th>
<th>Peak dc cyclic current for cables in series with rectifier (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>2400</td>
</tr>
</tbody>
</table>
### 7.2. Rectifier transformer to rectifier

EP 03 00 00 01 TI *Rectifier Transformer and Rectifier Characteristics* includes the various rectifier connection configurations used in the RailCorp 1500 V dc traction power supply system.

The cables connecting the rectifier transformer to rectifier shall have capacity for the applicable cyclic load profile. For load profiles with peak duration of less than two hours, the ac current at the peak of the cycle shall correspond to 150% of the rectifier continuous current rating. Figure 7 shows a typical rectifier transformer to rectifier connection.

![Rectifier transformer to rectifier connection diagram](image)

**Figure 7 - Typical rectifier transformer to rectifier connection**

The ratio of the ac current in each phase ($I_{ac}$) to the dc current ($I_{dc}$) for the various rectifier connection configurations are given in Table 2. For the typical load profile, the maximum ac currents at the peak of the cycle are given in Table 3.

### Table 2 - Ratio of ac to dc current of rectifier

<table>
<thead>
<tr>
<th>Rectifier connection configuration - Series, full wave bridge / Full wave bridge</th>
<th>Rectifier connection configuration - Quad Zig Zag</th>
<th>Rectifier connection configuration - Double Star</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_{ac} / I_{dc}$</td>
<td>0.816</td>
<td>0.144</td>
</tr>
</tbody>
</table>
Table 3 - Maximum cyclic ac current for cables between rectifier transformer and rectifier for a typical load profile

<table>
<thead>
<tr>
<th>Rectifier continuous rating (MW)</th>
<th>Maximum cyclic ac current (A) - Series, full wave bridge / Full wave bridge rectifier</th>
<th>Maximum cyclic ac current (A) - Quad Zig Zag rectifier</th>
<th>Maximum cyclic ac current (A) – Double Star rectifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>1958</td>
<td>346</td>
<td>694</td>
</tr>
<tr>
<td>4.0</td>
<td>3182</td>
<td>562</td>
<td>1127</td>
</tr>
<tr>
<td>5.0</td>
<td>3917</td>
<td>691</td>
<td>1387</td>
</tr>
</tbody>
</table>

7.3. Rectifier negative bus to main negative bus

For the typical arrangement as shown in Figure 3, the cables that connect between the rectifier negative bus and the main negative bus include the following:

- rectifier negative bus to reactor
- reactor to main negative bus

Figure 8 shows a typical rectifier negative bus to reactor connection.

![Figure 8 - Typical rectifier negative bus to reactor connection](image)

Figure 9 shows a typical reactor to main negative bus connection.
Table 4 shows the peak dc cyclic current for rating cables between rectifier negative bus and main negative bus for a typical load profile. The ratings allow for abnormal loading conditions with two rectifiers temporarily in service at the same time.

**Table 4 - Peak dc cyclic current for rating cables between rectifier negative bus and main negative bus for a typical load profile**

<table>
<thead>
<tr>
<th>Rectifier continuous rating (MW)</th>
<th>Peak dc cyclic current for cables between rectifier negative bus and main negative bus (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>3000</td>
</tr>
<tr>
<td>4.0</td>
<td>4875</td>
</tr>
<tr>
<td>5.0</td>
<td>6000</td>
</tr>
</tbody>
</table>

### 7.3.1. Temporary arrangement with two rectifiers in service

Most traction substations in the RailCorp 1500 V dc traction power supply system have only one rectifier in operation at any one time under normal operating conditions. Two rectifiers may be temporarily placed in service at the same time under abnormal loading conditions. To allow for such abnormal loading conditions, the cables connecting the rectifier negative bus and the main negative bus shall have a cyclic capacity for the applicable load profile.

For the typical load profile, the cable connection shall have capacity for a peak cyclic current of 125% of that carried by the rectifier. The cyclic current ratings of these cables are then 187.5% (1.25 x 1.5) of the continuous dc current rating of the rectifier, and are listed in Table 4 for the range of rectifier ratings existing in the 1500 V dc traction system.

Table 4 is not applicable if a substation is designed to have more than one rectifier in operation under normal conditions. The ratings of the cables shall be determined as part of the design process for such cases.
7.4. **Main negative bus to nearside negative bus**

Where there is only one nearside trackside negative bus connecting to the main negative bus and for a substation with only one rectifier in operation at any one time under normal operating conditions, the connection cables shall have capacity for the applicable cyclic load profile.

A minimum of two cables shall be provided between the main negative bus and the nearside trackside negative bus.

Figure 10 shows a typical main negative bus to nearside trackside negative bus connection.

![Diagram of main negative bus to nearside trackside negative bus connection](image)

**Figure 10 – Typical main negative bus to nearside trackside negative bus connection**

For a typical load profile the cable connection shall have the same cyclic current capacity as the cable connection between the rectifier negative bus and the main negative bus.

For substations with 2.5 MW rectifiers, the cable route design shall allow for future upgrade to 5 MW rectifiers.

7.4.1. **Locations with more than one nearside trackside negative bus**

Where a substation supplies two or more railway lines, more than one nearside trackside negative bus may be connected to the main negative bus. Typical connections to the nearside trackside negative buses under these circumstances are shown in Figure 11 and Figure 12. These arrangements occur where the substation is located at a junction.

Figure 11 shows an arrangement in which each nearside trackside negative bus is connected directly to the main negative bus. With this arrangement, the capacity of the cables shall be determined by design. However, each of the connections shall have a minimum capacity for a 4 MW rectifier supplying a single railway line.

Figure 12 shows an arrangement in which the nearside trackside negative buses are connected in series, with only one nearside trackside negative bus directly connected to the main negative bus.
bus. With this arrangement, the capacity of the connection to the first nearside trackside bus shall be determined in accordance with the rectifier rating and the applicable load profile. The connection between the two nearside trackside negative buses shall be determined by design, but shall have a minimum capacity as for the main negative bus to nearside trackside negative bus connection for a 4 MW rectifier supplying a single railway line.

A minimum of two cables shall be provided between the main negative bus and the nearside trackside negative bus.

![Figure 11 - Arrangement with each nearside trackside negative bus connected directly to main negative bus](image)

**Figure 11 – Arrangement with each nearside trackside negative bus connected directly to main negative bus**

![Figure 12 – Arrangement with nearside trackside negative buses connected in series](image)

**Figure 12 – Arrangement with nearside trackside negative buses connected in series**

### 7.5. Nearside trackside negative bus to farside trackside negative bus

The capacity requirements for the connection between the trackside negative buses shall be determined from the signalling design of the bonding arrangements of the traction rails. Typical bonding arrangements are given in ESG 100 *Signal Design Principles*.

The design of the trackside negative buses and their interconnection shall be coordinated with the signal system bonding design, especially for multi-track areas with atypical arrangements.
Figure 13 shows a typical nearside trackside negative bus to farside trackside negative bus connection.

![Diagram of typical nearside trackside negative bus to farside trackside negative bus connection]

The capacity of the connections between the nearside trackside negative bus and a farside trackside negative bus shall not be less than half of the capacity of the connection between the main negative bar and the nearside trackside negative bar.

Table 5 contains the minimum capacities for the typical load profile.

Where there is more than one nearside trackside negative bus, the connection between the nearside trackside negative bus and the farside trackside negative bus shall be determined by design, but shall have the minimum capacity as for a 4 MW rectifier with a single nearside trackside negative bus.

Where connections between the nearside trackside negative bus and a farside trackside negative bus exist for a location with a 2.5 MW rectifier, the design of the cable route shall be suitable for future upgrade to 5 MW rectifiers.

**Table 5 - Peak dc cyclic current for rating cables between nearside and farside trackside negative buses for the typical load profile**

<table>
<thead>
<tr>
<th>Rectifier continuous rating (MW)</th>
<th>Minimum peak dc cyclic current for cables between trackside negative buses (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>1500</td>
</tr>
<tr>
<td>4.0</td>
<td>2438</td>
</tr>
<tr>
<td>5.0</td>
<td>3000</td>
</tr>
</tbody>
</table>
8. Cable connections at sectioning hut

Typical cable connections at a sectioning hut are shown in Figure 14.

![Diagram of cable connections at sectioning hut]

Figure 14 - Typical cable connections at sectioning hut

The capacity requirements for the cables at a sectioning hut shall be determined by design.

The design shall be coordinated with the signal bonding arrangements.

Where rail connecting switches are provided at the sectioning hut, the cable connections shall be capable of carrying the fault current at the overhead wiring.

A minimum of two cables shall be provided for the connection between the sectioning hut and the nearside trackside negative bus.

9. DC feeder cables from substations and sectioning huts

Feeder cables from substations and sectioning huts to overhead wiring shall have a continuous current rating equal to or greater than that of the associated overhead wiring conductor system.

Guidance to the application of this requirement is given in Appendix B.

10. Cable connections in 1500 V field switches

Cables connecting two overhead wiring sections shall have a continuous current rating equal to or greater than that of the lesser of the two overhead wiring conductor systems.

Rail connection cables from switches shall be capable of carrying the fault current at the switch.

A minimum of two cables shall be provided for each rail connection.
11. **Bonding cable**

Bonding cables are used to interconnect exposed metallic parts in the vicinity of live 1500 V equipment, and connect them to the traction return circuit via a voltage limiting device such as a spark gap.

Bonding cables shall have sufficient capacity to carry the fault current.

Bonding circuits shall be arranged so that the voltage limiting device and the DCCB are operated in the event of a fault.

To mitigate the risk of copper theft, galvanised steel conductor with a polyvinyl chloride (PVC) sheath may be used to connect between the voltage limiting device and the traction rail in areas not normally accessible to the public.

Table 6 provides the approved cable types for bonding cables.

<table>
<thead>
<tr>
<th>Voltage rating</th>
<th>Cond area mm²</th>
<th>Insulation</th>
<th>Cable construction</th>
<th>Typical application</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6/1 kV</td>
<td>95</td>
<td>PVC</td>
<td>37/1.78 mm single copper conductor, PVC insulated, PVC sheathed and nylon covered (black) to specification SPG 1010 Cables for Railway Signalling Applications – General Requirements and SPG 1012 Cables for Railway Signalling Applications - Single and Twin Conductor Cables</td>
<td>Bonding cable</td>
</tr>
<tr>
<td>0.6/1 kV</td>
<td>-</td>
<td>PVC insulation provided by sheath</td>
<td>16 mm 6x25F-IWRC galvanised steel wire rope, grade 1770 minimum, Class 10 zinc coating to AS 3569, with orange 5V-90 PVC sheath, nominal thickness 1.3 mm.</td>
<td>Overhead wiring structure to rail bonding cable in areas not accessible to the public</td>
</tr>
</tbody>
</table>

12. **Approved cables and applications**

Approved cable types and typical applications for the RailCorp 1500 V dc traction power supply system are listed in Table 7 and Table 8.

Except where otherwise specified in the table, all approved cables shall have copper conductors.

The continuous current ratings of 240 mm² and 400 mm² XLPE and TR-XLPE cables are given in Appendix A.
Table 7 - Approved low voltage cables used in RailCorp 1500 V dc traction power supply system

<table>
<thead>
<tr>
<th>Voltage rating</th>
<th>Cond area mm²</th>
<th>Insulation</th>
<th>Cable construction</th>
<th>Typical application</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6/1 kV</td>
<td>95</td>
<td>PVC</td>
<td>37/1.78 mm single copper conductor, PVC insulated, PVC sheathed and nylon covered (black) to SPG 1010 Cables for Railway Signalling Applications – General Requirements and SPG 1012 Cables for Railway Signalling Applications - Single and Twin Conductor Cables</td>
<td>Bonding cable</td>
</tr>
<tr>
<td>0.6/1 kV</td>
<td>120</td>
<td>HD-90-CSP</td>
<td>608/0.5 mm flexible copper conductor, traction return bonding cable (orange) to SPG 1014 Cables for Railway Signalling Applications – Traction Return Bonding and Track Connection Cables.</td>
<td>Rail connection cable from 1500 V field switches Minimum of two cables required</td>
</tr>
<tr>
<td>0.6/1 kV</td>
<td>-</td>
<td>PVC insulation provided by sheath</td>
<td>16 mm 6x25F-IWRC galvanised steel wire rope, grade 1770 minimum, Class 10 zinc coating to AS 3569, with orange 5V-90 PVC sheath, nominal thickness 1.3 mm.</td>
<td>Overhead wiring structure to rail bonding cable in areas not accessible to the public</td>
</tr>
</tbody>
</table>
### Table 8 - Approved 6.6 kV cables used in RailCorp 1500 V dc traction power supply system

<table>
<thead>
<tr>
<th>Voltage rating kV</th>
<th>Cond area mm²</th>
<th>No of cores</th>
<th>Conductor</th>
<th>Conductor screen</th>
<th>Insulation</th>
<th>Insulation screen</th>
<th>Metallic screen</th>
<th>Oversheath</th>
<th>Typical application</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.8/6.6</td>
<td>16</td>
<td>1</td>
<td>stranded</td>
<td>semi-conductive XLPE</td>
<td>TR-XLPE</td>
<td>natural colour</td>
<td>extrusion by CCV or VCV</td>
<td>dry cure</td>
<td>Nil</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>circular</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rectifier input to auxiliary transformer</td>
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<tr>
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<td></td>
<td></td>
<td>compacted</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Feeder DCCB to control negative bus</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>copper</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Harmonic filter to control negative bus and 1500 V positive fuse where the harmonic filter and surge arrester are not truck-mounted</td>
</tr>
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<td></td>
<td></td>
<td>1500 V surge arrester to isolating switch</td>
</tr>
<tr>
<td>3.8/6.6</td>
<td>25</td>
<td>1</td>
<td>stranded</td>
<td>semi-conductive XLPE</td>
<td>TR-XLPE</td>
<td>natural colour</td>
<td>extrusion by CCV or VCV</td>
<td>dry cure</td>
<td>Nil</td>
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<td></td>
<td></td>
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<td></td>
<td>Rectifier input to auxiliary transformer</td>
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<td>compacted</td>
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<td></td>
<td></td>
<td>Feeder DCCB to control negative bus</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>copper</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Harmonic filter to control negative bus and 1500 V positive fuse where the harmonic filter and surge arrester are not truck-mounted</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1500 V surge arrester to isolating switch</td>
</tr>
<tr>
<td>Voltage rating kV</td>
<td>Cond area mm²</td>
<td>No of cores</td>
<td>Condutor</td>
<td>Conductor screen</td>
<td>Insulation</td>
<td>Insulation screen</td>
<td>Metallic screen</td>
<td>Oversheath</td>
<td>Typical application</td>
</tr>
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<td>-------------------</td>
</tr>
<tr>
<td>3.8/6.6</td>
<td>95</td>
<td>1</td>
<td>stranded</td>
<td>semi-conductive XLPE</td>
<td>TR-XLPE</td>
<td>Nil</td>
<td>Nil</td>
<td>Composite with 5V-90 PVC inner sheath, minimum thickness 2 mm, coloured orange</td>
<td>• Main negative bus to control negative bus</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>circular</td>
<td></td>
<td>natural colour</td>
<td></td>
<td></td>
<td>HDPE outer sheath, minimum thickness 2 mm, coloured black</td>
<td>• Main negative bus to voltmeter test rail</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>compacted copper</td>
<td></td>
<td>extrusion by CCV or VCV</td>
<td>dry cure</td>
<td></td>
<td></td>
<td>• Sectioning hut to nearside trackside negative bus. Minimum of two cables required</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Rail earth contactor to main negative bus or control negative bus. Minimum of two cables required</td>
</tr>
<tr>
<td>Voltage rating kV</td>
<td>Cond area mm²</td>
<td>No of cores</td>
<td>Conductor</td>
<td>Conductor screen</td>
<td>Insulation</td>
<td>Insulation screen</td>
<td>Metallic screen</td>
<td>Oversheath</td>
<td>Typical application</td>
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<td>-------------------</td>
</tr>
<tr>
<td>3.8/6.6</td>
<td>240</td>
<td>1</td>
<td>stranded</td>
<td>semi-conductive XLPE</td>
<td>TR-XLPE</td>
<td>Nil</td>
<td>Nil</td>
<td>Composite with</td>
<td>Rectifier negative to rectifier negative link</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>circular</td>
<td></td>
<td>natural colour</td>
<td></td>
<td></td>
<td>5V-90 PVC inner sheath, minimum thickness 2 mm, coloured orange</td>
<td>Rectifier negative link to rectifier negative bus</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>compacted</td>
<td></td>
<td>extrusion by CCV or VCV</td>
<td>dry cure</td>
<td></td>
<td>HDPE outer sheath, minimum thickness 2 mm, coloured black</td>
<td>Main negative bus to feeder isolating and rail connecting links</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>copper</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rectifier transformer to rectifier input</td>
<td>Rectifier negative bus to reactor</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Reactor to main negative bus</td>
<td>Reactor to main negative bus</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Main negative bus to nearside trackside negative bus. Minimum of two cables required.</td>
<td>Main negative bus to nearside trackside negative bus. Minimum of two cables required.</td>
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<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Connection between trackside negative buses</td>
<td>Connection between trackside negative buses</td>
</tr>
<tr>
<td>Voltage rating kV</td>
<td>Cond area mm²</td>
<td>No of cores</td>
<td>Conductor</td>
<td>Conductor screen</td>
<td>Insulation</td>
<td>Insulation screen</td>
<td>Metallic screen</td>
<td>Oversheath</td>
<td>Typical application</td>
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<td>---------------------</td>
</tr>
<tr>
<td>3.8/6.6</td>
<td>400</td>
<td>1</td>
<td>stranded</td>
<td>semi-conductive XLPE</td>
<td>TR-XLPE</td>
<td>Nil</td>
<td>Nil</td>
<td>Composite with 5V-90 PVC inner sheath, minimum thickness 2 mm, coloured orange, HDPE outer sheath, minimum thickness 2 mm, coloured black</td>
<td>Rectifier negative to rectifier negative link, Rectifier negative link to rectifier negative bus, Main negative bus to feeder isolating and rail connecting links, Rectifier transformer to rectifier input, Rectifier negative bus to reactor, Reactor to main negative bus, Main negative bus to nearside trackside negative bus, Connection between trackside negative buses</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>circular</td>
<td></td>
<td>natural colour</td>
<td>extrusion by CCV or VCV</td>
<td>dry cure</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>compacted</td>
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<td></td>
<td></td>
<td></td>
<td>copper</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>3.8/6.6</td>
<td>400</td>
<td>1</td>
<td>1159/0.67 mm stranded multiple circular</td>
<td>semi-conductive cross-linked</td>
<td>EPR XR-EP-90</td>
<td>Nil</td>
<td>Nil</td>
<td>HD-90-CPE or HD-90-TPE</td>
<td>Rectifier transformer to rectifier input</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>tin annealed copper</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Voltage rating kV</td>
<td>Cond area mm²</td>
<td>No of cores</td>
<td>Conductor</td>
<td>Conductor screen</td>
<td>Insulation</td>
<td>Insulation screen</td>
<td>Metallic screen</td>
<td>Oversheath</td>
<td>Typical application</td>
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</tr>
<tr>
<td>3.8/6.6</td>
<td>240</td>
<td>1</td>
<td>stranded</td>
<td>semi-conductive</td>
<td>TR-XLPE</td>
<td>semi-conductive</td>
<td>Plain annealed</td>
<td>Composite with</td>
<td>Rectifier positive to</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>circular</td>
<td>XLPE</td>
<td></td>
<td>XLPE</td>
<td>copper wire</td>
<td>HDPE outer sheath,</td>
<td>rectifier DCCB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>compacted</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>minimum thickness</td>
<td>Feeder DCCB to</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>copper</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2 mm, coloured</td>
<td>feeder isolating links</td>
</tr>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>orange</td>
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<tr>
<td>3.8/6.6</td>
<td>400</td>
<td>1</td>
<td>stranded</td>
<td>semi-conductive</td>
<td>TR-XLPE</td>
<td>semi-conductive</td>
<td>Plain annealed</td>
<td>Composite with</td>
<td>Rectifier positive to</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>circular</td>
<td>XLPE</td>
<td></td>
<td>XLPE</td>
<td>copper wire</td>
<td>HDPE outer sheath,</td>
<td>rectifier DCCB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>compacted</td>
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<td></td>
<td></td>
<td></td>
<td>minimum thickness</td>
<td>Feeder DCCB to</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>copper</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2 mm, coloured</td>
<td>feeder isolating links</td>
</tr>
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<td>orange</td>
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</tr>
</tbody>
</table>

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Appendix A  Current ratings of 240 mm² and 400 mm² XLPE and TR-XLPE cables

A.1. Reference conditions

The current ratings given in this appendix are based on:

- maximum allowable conductor temperature
- emissivity of cable
- environmental conditions
- installation conditions

A.1.1 Maximum allowable conductor temperature under normal operation

The maximum allowable conductor temperature for XLPE and TR-XLPE insulated cables is 90 °C.

A.1.2 Emissivity of cable

An emissivity of 0.7 for cables is applied.

A.1.3 Reference environmental and installation conditions

Reference environmental and installation conditions are used to determine the cable ratings.

Reference conditions exist for the following:

- buried cables
- cables in air
- cables in galvanized steel troughing (GST)

A.1.3.1 Conditions for buried cables

The set of environmental conditions for buried cables includes the following:

- ambient soil temperature – 25 °C
- soil thermal resistivity – 1.2 K.m/W

The set of installation conditions for buried cables include the following:

- depth of burial – 800 mm
- duct diameter – 150 mm
A.1.3.2 Conditions for cables in air

The set of environmental conditions for cables in air includes the following:

- air temperature (ambient) – 40 °C
- solar radiation – 1000 W/m³

The set of installation conditions for cables in air includes the following:

- free air circulation around cable

A.1.3.3 Conditions for cables in galvanized steel troughing

The set of environmental conditions for cables in GST includes the following:

- air temperature (ambient) – 40 °C
- solar radiation – 1000 W/m³

The set of installation conditions for cables in GST includes the following:

- size of GST – 150 mm x 150 mm or 200 mm x 200 mm
- GST emissivity – 0.5
- thermal resistivity of GST walls – 0.013 K.m/W
- GST wall thickness – 2 mm
- cables are installed within the same GST
- all cables are touching
- ventilation slots are not provided with the GST
- lining to protect cables from grass fires is not installed in the GST

A.2. Cable ratings

Table 9 and Table 10 give the current ratings for groups of up to three cables.

For arrangements with more than three cables, the 'as installed' cable ratings are to be determined in the design process.

For the purpose of cable ratings, the effect from the presence of cable screens may be ignored.

The ratings of TR-XLPE cables are the same as those of XLPE cables.
### Table 9 - Continuous direct current ratings of 240 mm² XLPE cables

<table>
<thead>
<tr>
<th>No of cables</th>
<th>Direct buried</th>
<th>Buried in duct</th>
<th>In air in shade</th>
<th>In air in sun</th>
<th>In GST in shade</th>
<th>In GST in sun</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>750 A</td>
<td>580 A</td>
<td>675 A</td>
<td>520 A</td>
<td>635 A</td>
<td>525 A</td>
</tr>
<tr>
<td>2</td>
<td>1200 A</td>
<td>945 A</td>
<td>1225 A</td>
<td>950 A</td>
<td>900 A</td>
<td>745 A</td>
</tr>
<tr>
<td>3</td>
<td>1565 A</td>
<td>1255 A</td>
<td>1710 A</td>
<td>1320 A</td>
<td>1105 A</td>
<td>910 A</td>
</tr>
</tbody>
</table>

### Table 10 - Continuous direct current ratings of 400 mm² XLPE cables

<table>
<thead>
<tr>
<th>No of cables</th>
<th>Direct buried</th>
<th>Buried in duct</th>
<th>In air in shade</th>
<th>In air in sun</th>
<th>In GST in shade</th>
<th>In GST in sun</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>970 A</td>
<td>770 A</td>
<td>920 A</td>
<td>700 A</td>
<td>855 A</td>
<td>710 A</td>
</tr>
<tr>
<td>2</td>
<td>1530 A</td>
<td>1250 A</td>
<td>1650 A</td>
<td>1260 A</td>
<td>1205 A</td>
<td>1010 A</td>
</tr>
<tr>
<td>3</td>
<td>1960 A</td>
<td>1655 A</td>
<td>2260 A</td>
<td>1750 A</td>
<td>1475 A</td>
<td>1220 A</td>
</tr>
</tbody>
</table>
Appendix B  Guide to current rating requirements for 1500 V dc feeder cables

B.1. Current ratings of 1500 V dc feeder cables

Feeder cables generally have a minimum design life of 40 years. The requirement in Section 9 in this standard is to ensure that the feeder cables are not the limiting factor in the capacity of the 1500 V dc traction power supply. The requirement applies to all stages of the asset life cycle up to the maintenance stage, including the development of concept and reference design.

This requirement should be read in conjunction with the provision in the following Transport standards:

- T HR EL 90003 ST Heavy Rail Traction System – Current Ratings of 1500 V dc Equipment
- T HR EL 08010 ST Overhead Wiring Conductor System Selection

The continuous current rating requirement of T HR EL 90003 ST does not apply to the feeders between the overhead wiring (OHW) and substation or sectioning hut.

B.1.1 OHW system continuous current carrying capacity

Typical continuous current capacity for OHW conductor systems with typical wire run characteristics are given in T HR EL 08010 ST.

For 400 mm$^2$ XLPE cables buried in ducts under the reference conditions listed in Appendix A, an estimate of the number of cables required for each of the 'current' OHW conductor systems is given in Table 11.

Table 11 - Number of 400 mm$^2$ XLPE cables buried in ducts per feeder

<table>
<thead>
<tr>
<th>OHW system</th>
<th>Area 1</th>
<th>Area 2</th>
<th>Area 3</th>
<th>Tunnel</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>N/A</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>N/A</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>N/A</td>
</tr>
<tr>
<td>12</td>
<td>&gt;3</td>
<td>3</td>
<td>3</td>
<td>N/A</td>
</tr>
<tr>
<td>15</td>
<td>&gt;3</td>
<td>3</td>
<td>3</td>
<td>N/A</td>
</tr>
<tr>
<td>28</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>2</td>
</tr>
</tbody>
</table>

The actual number of cables required at a specific location should be determined from cable ampacity calculations with appropriate derating factors applied for the ambient conditions applicable to the location and the cable installation configuration.

The geographical extent of the areas listed in Table 11 is defined in EP 00 00 00 13 SP Electrical Power Equipment – Design Ranges of Ambient Conditions.
B.1.2 Power study requirements

The minimum current ratings of feeders for a project are generally determined from power studies. If the feeder minimum continuous current rating from the power study is less than, but within 10%, of that of the associated OHW, a sensitivity analysis should be conducted as part of the power study. This sensitivity analysis should be done by calculating the maximum root mean square (rms) of the feeder current over periods of:

- one hour
- 30 minutes
- 15 minutes

If the largest of the three rms values is greater than 95% of the continuous current rating of the OHW, the feeder capacity as determined by the power study is satisfactory, and the requirement of Section 9 is deemed to have been met.

B.2. Request for concession

Where a design AEO has determined that it is not reasonably practicable to comply with the requirement of Section 9, the request for concession should be accompanied by documented supporting information addressing the following considerations:

- project requirements
- spare capacity for growth
- results of stakeholder consultation on maintenance requirements, existing asset condition and asset management planning
- results of stakeholder consultation on the likelihood of future growth

B.2.1 Project requirements

The minimum current ratings of feeders for the project should be stated in the request for concession. This is generally an output from a power study.

B.2.2 Spare capacity for growth

The spare capacity for growth from the proposed configuration is illustrated in Figure 15. The difference between the proposed design continuous current rating of the feeder and the minimum rating required by the power study should be documented. This difference should be stated in amperes and also as a percentage of the minimum rating.
B.2.3 Maintenance requirements consultation

Consultation with TfNSW operator and maintainer should include the following considerations as a minimum:

- maintainability of the proposed cable installation configuration
- conditions of relevant existing assets, especially if some of the existing feeder cables are to be retained
- aspects of the asset management plan that may affect or be impacted by the proposed installation

Where the operator and maintainer is Sydney Trains, the maintenance requirements consultation should be made via the Engineering and Maintenance Interface Unit within Sydney Trains. Refer to https://www.transport.nsw.gov.au/sydneytrains/commercial/building-near-railway for contact information.

B.2.4 Likelihood of future growth

Consultation with relevant stakeholders should be made to obtain planning information on projects that may have an impact on the required rating of the feeder, and the likelihood and timeframes for the projects. Examples of such projects include:

- procurement of rolling stock fleet
- proposed stabling facilities
- changes in network configuration
- changes in train operating conditions or timetables
Consultation for future growth should be made with the Rail Program Delivery branch of the TfNSW Infrastructure and Services division.