High Voltage AC and 1500 V DC Traction Power Supply Cable Requirements

Version 2.0

Issue date: 13 March 2019
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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>
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<tbody>
<tr>
<td>1.0</td>
<td>First issued, 12 March 2014</td>
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</table>
| 2.0     | Second issue.  
The changes to previous issue include the following:  
- incorporation of the contents of technical notes TN 086: 2014 and TN 009: 2018  
- removal of the requirement for provision of integrated optic fibres for temperature monitoring  
- minor amendments and clarification to content |
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 provides the technical requirements for the approved high voltage ac and 1500 V dc traction power supply cable types and sizes.

This is a second issue. The changes to previous content include the following:

- incorporation of the contents of technical notes TN 086: 2014 and TN 009: 2018
- removal of the requirement for provision of integrated optic fibres for temperature monitoring
- minor amendments and clarification to content
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1. **Introduction**

TfNSW has a high voltage (HV) distribution network that supplies electricity to the traction substations, railway stations and other elements of the TfNSW Metropolitan Heavy Rail Network (formerly known as RailCorp network). Feeders of this HV distribution network consist of both cables and overhead conductors with nominal voltages of between 11 kV and 132 kV. A very small number of feeders with a nominal voltage of 2 kV exist in the network. These feeders are gradually being phased out. Cables with rated voltage 3.8/6.6 kV are also used in the 1500 V dc traction power supply system in the TfNSW Metropolitan Heavy Rail Network.

2. **Purpose**

This document provides the technical requirements for approved HV ac and 1500 V dc traction power supply cable types and sizes.

2.1. **Scope**

This document sets out the technical requirements for approved HV ac and 1500 V dc traction power supply cable types in the TfNSW Metropolitan Heavy Rail Network and for the TfNSW HV distribution network (also known as RailCorp HV distribution network).

Refer to TS TOC 1 *Train Operating Conditions (TOC) Manual – General Instructions* which defines the areas associated with the network.

This document also specifies the cable sizes in order to rationalise the number of different cable sizes in service.

1500 V dc traction power supply cables include:

- 1500 V positive cables
- connection cables between power equipment within a traction substation
- 1500 V negative cables for connection between:
  - traction substations and nearside trackside negative bus
  - sectioning hut and nearside trackside negative bus
  - trackside negative buses

The material procurement guidelines with respect to packaging are provided in Appendix B.

The material procurement guidelines with respect to information requirements for request for tender are provided in Appendix C.

This document does not cover requirements for the design and construction of cable installations.
2.2. **Application**

This document applies to all HV ac and 1500 V dc traction power supply cables for all new work, and alterations to existing installations of such cables. For alterations to existing cable installations, the requirements of this document are applicable to new cables installed in the alteration works only.

This document does not apply to:

- control and instrumentation cables
- traction bonding cables between rails and between trackside negative buses and rail
- cables used in rolling stock

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 (all parts)

**Australian standards**

- AS/NZS 1429.1 Electric cables – Polymeric insulated Part 1: For working voltages 1.9/3.3 (3.6) kV up to and including 19/33 (36) kV
- AS/NZS 1429.2 Electric cables – Polymeric insulated Part 2: For working voltages above 19/33 (36) kV up to and including 87/150 (170) kV
- AS/NZS 2893 Electric cables – Lead and lead alloy sheaths – Composition
- AS/NZS 3808 Insulating and sheathing materials for electric cables
- AS/NZS 4507 Cables – Classification of characteristics when exposed to fire

**Transport for NSW standards**

- ESC 340 Tunnels
- T HR EL 20002 ST 1500 V DC Cables and Cable Ratings
- TS TOC 1 Train Operating Conditions (TOC) Manual – General Instructions

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

derating the change in the actual current carrying capacity of a cable from its nominal rating due to deviation of actual installation conditions from the referenced conditions

EPR a cross-linked compound of ethylene and propylene copolymer or terpolymer, suitable for up to 90 °C maximum continuous operating temperature (AS/NZS 3808)

HDPE high density polyethylene

HV high voltage; voltage exceeding 1000 V ac

NATA National Association of Testing Authorities, Australia

PVC polyvinyl chloride

TfNSW Transport for New South Wales

TR-XLPE tree retardant XLPE

XLPE a compound of cross-linked polyethylene, suitable for up to 90 °C maximum continuous operating temperature (AS/NZS 3808)

5. General requirements

High voltage (HV) cables shall comply with the requirements of AS/NZS 1429.1 Electric cables – Polymeric insulated Part 1: For working voltages 1.9/3.3 (3.6) kV up to and including 19/33 (36) kV or AS/NZS 1429.2 Electric cables – Polymeric insulated Part 2: For working voltages above 19/33 (36) kV up to and including 87/150 (170) kV as applicable to voltage rating, with the following exceptions:

- the minimum thickness of oversheath shall comply with the requirements provided in Section 9
- metre marking shall comply with the requirements provided in Section 7

11 kV cables shall be used for new cables required for alterations to the 2 kV system.

Cable types that do not comply with this standard but are 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 maintenance AEO.

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

Cables with integrated optic fibres in existing stock may continue to be used, provided that the cables comply with all other requirements of this standard. The optic fibres shall be cut and sealed at cable joints and terminations.
6. **Design life**

Unless otherwise specified by project requirements, cables shall have a design life of 40 years minimum with the conditions under which the cable is to be installed.

7. **Metre marking on cable**

Metre marking shall be provided in accordance with AS/NZS 1429.1 or AS/NZS 1429.2 as appropriate to the voltage rating. Numbering shall begin with zero at the hub of each cable drum.

8. **Installation and site conditions**

The designer shall take into account the installation and site conditions in specifying the cable for each project. Provisions in addition to those set out in this standard may be required to achieve the required design life.

8.1. **Underwater installations**

Cables manufactured and supplied in accordance with this standard may be installed at locations where the cables are immersed in water under seasonal conditions. However, such cables are not suitable for installations for which the cables are permanently immersed in water. The designer shall determine the exposure of the cable to water immersion through suitable hydrology studies.

8.2. **Anti-termite protection**

Provisions may be made for anti-termite protection in areas with known termite infestation. Evidence of effectiveness of proposed termite solution with relevant Australian termite species shall be provided.

9. **Approved cable types and applications**

Approved cable types shall be used for the following:

- 6.6 kV cables used in the 1500 V dc traction power supply system
- 11 kV
- 33 kV
- 66 kV

The approved cable types and their application are included in Section 9.1 to Section 9.4.

Currently there is no approved 132 kV cable type.
Cables used in tunnels or underground stations shall meet additional requirements given in Section 12.

9.1. **6.6 kV cables approved for use in 1500 V dc traction power supply system**

Refer to T HR EL 20002 ST *1500 V DC Cables and Cable Ratings* for details of 6.6 kV cables that shall be used in the 1500 V dc traction power supply system.
### 9.2. Cables approved for use with 11 kV

The cables that shall be used with 11 kV are described and included in Table 1.

<table>
<thead>
<tr>
<th>Voltage rating (kV)</th>
<th>Cond area (mm$^2$)</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>Fillers and tapes</th>
<th>Oversheath</th>
<th>Typical application</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.35/11</td>
<td>35</td>
<td>1</td>
<td>stranded, circular, compacted copper</td>
<td>Semi-conductive XLPE</td>
<td>TR-XLPE natural colour, triple extrusion by CCV or VCV, dry cure</td>
<td>semi-conductive XLPE, hand strippable without pre-conditioning</td>
<td>plain annealed copper wire, CSA equal to core area</td>
<td>N/A</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>Cable runs between electrical equipment within a substation</td>
</tr>
<tr>
<td>6.35/11</td>
<td>240</td>
<td>1</td>
<td>stranded, circular, compacted copper</td>
<td>Semi-conductive XLPE</td>
<td>TR-XLPE natural colour, triple extrusion by CCV or VCV, dry cure</td>
<td>semi-conductive XLPE, hand strippable without pre-conditioning</td>
<td>plain annealed copper wire, CSA 90 mm$^2$</td>
<td>N/A</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>Feeder</td>
</tr>
<tr>
<td>6.35/11</td>
<td>300</td>
<td>1</td>
<td>stranded, circular, compacted copper</td>
<td>Semi-conductive XLPE</td>
<td>TR-XLPE natural colour, triple extrusion by CCV or VCV, dry cure</td>
<td>semi-conductive XLPE, hand strippable without pre-conditioning</td>
<td>plain annealed copper wire, CSA 90 mm$^2$</td>
<td>N/A</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>Project specific needs</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>Fillers and tapes</td>
<td>Oversheath</td>
<td>Typical application</td>
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<tr>
<td>6.35/11</td>
<td>95</td>
<td>3</td>
<td>stranded</td>
<td>Semi-conductive XLPE</td>
<td>TR-XLPE</td>
<td>semi-conductive XLPE</td>
<td>individually screened with plain annealed copper wire</td>
<td>Laid up polypropylene fillers and taped</td>
<td>Composite with: 5V-90 PVC inner sheath, minimum thickness 2 mm, coloured orange</td>
<td>Feeder</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>circular</td>
<td></td>
<td></td>
<td>natural colour</td>
<td>hand strippable without preconditioning</td>
<td></td>
<td>HDPE outer sheath, minimum thickness 2 mm, coloured black</td>
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<td></td>
<td></td>
<td></td>
<td>compacted</td>
<td></td>
<td></td>
<td>triple extrusion by CCV or VCV</td>
<td>dry cure</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>6.35/11</td>
<td>150</td>
<td>3</td>
<td>stranded,</td>
<td>Semi-conductive XLPE</td>
<td>TR-XLPE</td>
<td>semi-conductive XLPE</td>
<td>individually screened with plain annealed copper wire</td>
<td>Laid up polypropylene fillers and taped</td>
<td>Composite with: 5V-90 PVC inner sheath, minimum thickness 2 mm, coloured orange</td>
<td>Feeder</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>circular</td>
<td></td>
<td></td>
<td>natural colour</td>
<td>hand strippable without preconditioning</td>
<td></td>
<td>HDPE outer sheath, minimum thickness 2 mm, coloured black</td>
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<td>compacted</td>
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<td></td>
<td>triple extrusion by CCV or VCV</td>
<td>dry cure</td>
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<td>copper</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>6.35/11</td>
<td>240</td>
<td>3</td>
<td>stranded,</td>
<td>Semi-conductive XLPE</td>
<td>TR-XLPE</td>
<td>semi-conductive XLPE</td>
<td>individually screened with plain annealed copper wire</td>
<td>Laid up polypropylene fillers and taped</td>
<td>Composite with: 5V-90 PVC inner sheath, minimum thickness 2 mm, coloured orange</td>
<td>Feeder</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>circular</td>
<td></td>
<td></td>
<td>natural colour</td>
<td>hand strippable without preconditioning</td>
<td></td>
<td>HDPE outer sheath, minimum thickness 2 mm, coloured black</td>
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</tbody>
</table>
9.3. Cables approved for use with 33 kV

The cables that shall be used with 33 kV are described and included in Table 2.

<table>
<thead>
<tr>
<th>Voltage rating (kV)</th>
<th>Cond area (mm$^2$)</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>Fillers and tapes</th>
<th>Oversheath</th>
<th>Typical application</th>
</tr>
</thead>
<tbody>
<tr>
<td>19/33</td>
<td>120</td>
<td>1</td>
<td>stranded, circular compacted copper</td>
<td>Semi-conductive XLPE</td>
<td>TR-XLPE</td>
<td>• semi-conductive XLPE • hand strippable without pre-conditioning</td>
<td>• plain annealed copper wire • CSA 90 mm$^2$</td>
<td>N/A</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>• 33 kV switchgear to rectifier transformer (all sizes) • 33 kV cables for 33/11 kV transformer up to 7.5 MVA capacity</td>
</tr>
<tr>
<td>19/33</td>
<td>300</td>
<td>1</td>
<td>stranded, circular compacted copper</td>
<td>Semi-conductive XLPE</td>
<td>TR-XLPE</td>
<td>• semi-conductive XLPE • hand strippable without pre-conditioning</td>
<td>• plain annealed copper wire • CSA 90 mm$^2$</td>
<td>N/A</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>Feeder</td>
</tr>
<tr>
<td>19/33</td>
<td>400</td>
<td>1</td>
<td>stranded, circular compacted copper</td>
<td>Semi-conductive XLPE</td>
<td>TR-XLPE</td>
<td>• semi-conductive XLPE • hand strippable without pre-conditioning</td>
<td>• plain annealed copper wire • CSA 90 mm$^2$</td>
<td>N/A</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>Feeder</td>
</tr>
<tr>
<td>Voltage rating (kV)</td>
<td>Cond area (mm$^2$)</td>
<td>No of cores</td>
<td>Conductor</td>
<td>Conductor screen</td>
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<tr>
<td>19/33</td>
<td>500</td>
<td>1</td>
<td>stranded, circular</td>
<td>Semi-conductive XLPE</td>
<td>TR-XLPE</td>
<td>natural colour</td>
<td>semi-conductive XLPE</td>
<td>plain annealed copper wire</td>
<td>N/A</td>
<td>Composite with: 5V-90 PVC inner sheath, minimum thickness 2 mm, coloured orange</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>compacted copper</td>
<td></td>
<td></td>
<td>triple extrusion by CCV or VCV</td>
<td>hand strippable without pre-conditioning</td>
<td>CSA 90 mm$^2$</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>dry cure</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>19/33</td>
<td>630</td>
<td>1</td>
<td>stranded, circular</td>
<td>Semi-conductive XLPE</td>
<td>TR-XLPE</td>
<td>natural colour</td>
<td>semi-conductive XLPE</td>
<td>plain annealed copper wire</td>
<td>N/A</td>
<td>Composite with: 5V-90 PVC inner sheath, minimum thickness 2 mm, coloured orange</td>
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<tr>
<td>19/33</td>
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<td>TR-XLPE</td>
<td>natural colour</td>
<td>semi-conductive XLPE</td>
<td>individually screened with plain annealed copper wire</td>
<td>Laid up polypropylene fillers and taped</td>
<td>Composite with: 5V-90 PVC inner sheath, minimum thickness 2 mm, coloured orange</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>compacted copper</td>
<td></td>
<td></td>
<td>triple extrusion by CCV or VCV</td>
<td>hand strippable without pre-conditioning</td>
<td>CSA 90 mm$^2$ total</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>dry cure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19/33</td>
<td>300</td>
<td>3</td>
<td>stranded, circular</td>
<td>Semi-conductive XLPE</td>
<td>TR-XLPE</td>
<td>natural colour</td>
<td>semi-conductive XLPE</td>
<td>individually screened with plain annealed copper wire</td>
<td>Laid up polypropylene fillers and taped</td>
<td>Composite with: 5V-90 PVC inner sheath, minimum thickness 2 mm, coloured orange</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>compacted copper</td>
<td></td>
<td></td>
<td>triple extrusion by CCV or VCV</td>
<td>hand strippable without pre-conditioning</td>
<td>CSA 90 mm$^2$ total</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>dry cure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
9.4. Cables approved for use with 66 kV

The cables that shall be used with 66 kV are described and included in Table 3. All approved 66 kV cables are single core cables.

Table 3 - Approved 66 kV cables

<table>
<thead>
<tr>
<th>Voltage rating (kV)</th>
<th>Cond area (mm²)</th>
<th>Conductor</th>
<th>Conductor screen</th>
<th>Insulation</th>
<th>Insulation screen</th>
<th>Water blocking</th>
<th>Metallic moisture barrier</th>
<th>Metallic screen</th>
<th>Binder tapes</th>
<th>Oversheath</th>
<th>Typical application</th>
</tr>
</thead>
<tbody>
<tr>
<td>38/66</td>
<td>95</td>
<td>stranded, circular compacted copper</td>
<td>non-hygroscopic semi-conductive tape followed by semi-conductive XLPE</td>
<td>XLPE</td>
<td>natural colour triple extrusion by CCV or VCV; VCV preferred dry cure</td>
<td>semi-conductive XLPE fully bonded to insulation, that is, not hand strippable</td>
<td>non-bio-degradable, water swellable semi-conductive tape applied under the metallic moisture barrier</td>
<td>Lead alloy E to AS/NZS 2893</td>
<td>plain annealed copper wire suitable for fault rating of 13 kA for one second</td>
<td>To be compatible with the material with which they are in contact 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 transformer cable</td>
</tr>
<tr>
<td>38/66</td>
<td>150</td>
<td>stranded, circular compacted copper</td>
<td>non-hygroscopic semi-conductive tape followed by semi-conductive XLPE</td>
<td>XLPE</td>
<td>natural colour triple extrusion by CCV or VCV; VCV preferred dry cure</td>
<td>semi-conductive XLPE fully bonded to insulation, that is, not hand strippable</td>
<td>non-bio-degradable, water swellable semi-conductive tape applied under the metallic moisture barrier</td>
<td>Lead alloy E to AS/NZS 2893</td>
<td>plain annealed copper wire suitable for fault rating of 13 kA for one second</td>
<td>To be compatible with the material with which they are in contact Composite with: 5V-90 PVC inner sheath, minimum thickness 2 mm, coloured orange HDPE outer sheath, minimum thickness 2 mm, coloured black</td>
<td>Feeder</td>
</tr>
</tbody>
</table>
10. Ratings

Continuous current ratings for approved cables are based on the following:

- maximum allowable conductor temperature under continuous operation
- emissivity of cable
- environmental conditions
- installation conditions

Derating shall be applied where there is variation to the reference environmental or installation conditions.

Cable ratings shall take into account emergency operation conditions.

Phase conductors and metallic screens require ratings for short circuit operations.

10.1. Maximum allowable conductor temperature under continuous operation

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

The maximum allowable conductor temperature for existing paper-insulated cables is 70 °C.

10.2. Emissivity of cable

An emissivity of 0.7 for cables is applicable to the continuous current ratings. For cables with different emissivity values, the continuous current ratings shall be determined in accordance with IEC 60287 Electric cables – Calculation of the current rating (all parts) using appropriate software that have been accepted by the relevant AEO.

10.3. Reference environmental and installation conditions

A set of reference environmental and installation conditions is used to determine the continuous current ratings specified in Section 10.7. The actual environmental and installation conditions applicable to a project are generally different from the reference conditions.

Reference conditions exist for the following:

- buried cables
- cables in air
10.3.1. Reference conditions for buried cables

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

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

The set of reference installation conditions for buried cables includes the following:

- depth of burial – 800 mm
- direct buried single core cables are in close trefoil formation
- duct diameter – 150 mm
- number of cables in each duct – 1
- ducts of single core cables are arranged in close trefoil formation
- metallic screens – solidly bonded at both ends

10.3.2. Reference conditions for cables in air

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

- air temperature (ambient) – 40 °C
- solar radiation – 1000 W/m²

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

- steel troughing emissivity – 0.5
- troughing size – 150 mm x 150 mm
- number of circuits in each troughing – 1
- free air circulation around each cable circuit for cables not in an enclosure
- single core cables are in close trefoil formation
- metallic screens – solidly bonded at both ends

10.4. Derating

Where there is variation to the reference environmental or installation conditions, derating shall be applied.

For simple installation configurations and for cables with a nominal voltage up to 33 kV, it is acceptable to apply derating factors published by the relevant cable manufacturer.
For more complex installation configurations, the 'as-installed' current rating shall be determined in accordance with IEC 60287 using appropriate software that have been accepted by the relevant AEO.

Derating assessments shall take into account the following factors:

- ambient temperature
- proximity
- depth of installation
- thermal resistivity
- eddy and circulating currents

10.4.1. Derating for ambient temperature

Where the ambient air or soil temperature is different from the reference conditions, the cable ratings are subject to derating.

10.4.2. Derating for cables in close proximity

Current ratings are subject to derating where a number of circuits are installed in close proximity to one another.

With cables in ground, a derating factor shall be applied when the spacing between circuits is less than 1.0 m.

Cables in air shall be derated when the spacing between circuits is less than three times the individual cable diameter.

10.4.3. Derating for depth of installation

Cables installed in ground at depths different to the reference conditions are subject to derating. This applies to both direct buried and ducted installations.

Derating for depth has particular relevance to cables in ducts installed by directional boring.

The cable manufacturer should be consulted for guidance regarding derating factors applicable to 66 kV cables.

10.4.4. Derating for soil thermal resistivity

Some soils such as marshy ground, coarse sand and reclaimed and rubbish ground generally exhibit thermal resistivity values higher than the reference conditions. For installations in soils of poor thermal resistivity, it is an accepted practice to measure soil thermal resistivity prior to selecting cable size and either applying a derating factor or, preferably, employing installation...
techniques that will remediate the situation. Installation techniques include bedding cables and backfilling trenches with material of low thermal resistivity such as 14:1 sand cement mix.

As heat is generated by current ($I^2R$) and not by voltage, this situation is applicable to all cables and not just higher voltage cables.

10.4.5. Derating for eddy and circulating currents

The continuous current ratings are based on installations with the metallic screens solidly bonded to earth at both ends, with eddy and circulating current losses ignored.

The designer shall assess the effect eddy and circulating current losses for actual conditions. In particular, careful consideration should be given to the following situations:

- cables with rated voltage of 66 kV or above
- cable runs longer than 3.5 km
- single core cables not installed in a close configuration for significant portions of the route

Alternative bonding configuration shall be taken into account for these situations to determine the cable size that will provide the optimum whole-of-life costs.

10.5. Emergency operation ratings

Cables shall be designed for emergency operation conditions as set out in AS/NZS 1429.1 or AS/NZS 1429.2 as appropriate to the voltage rating. Derating factors shall be applied for the installation and site conditions.

10.6. Short-circuit operation ratings

The phase conductors and metallic screens shall be rated to carry the maximum earth fault current at the location for the longest clearing time of the backup protection covering that fault.

The phase conductors shall be rated to carry the maximum three-phase fault current for the longest clearing time of the backup protection covering that fault.

The maximum conductor temperature under short-circuit operation conditions shall comply with AS/NZS 1429.1 or AS/NZS 1429.2 as appropriate to the voltage rating.

10.7. Approved cables ratings

Reference continuous current ratings for the approved cables are listed in Table 4, Table 5 and Table 6 when operated under the reference conditions.

Refer to T HR EL 20002 ST for the ratings of 3.8/6.6 kV cables when used as 1500 V dc cables and with the cyclic loading conditions applicable to the 1500 V dc traction power supply system.
The existing TfNSW HV distribution network contains various cable types and sizes that are not permitted to be used for new installations. For information purposes, the ratings of these cables are given in Appendix A.

### Table 4 – 11 kV cables with TR-XLPE insulation – Continuous current ratings

<table>
<thead>
<tr>
<th>Conductor area mm²</th>
<th>No of cores</th>
<th>Direct buried (A)</th>
<th>Buried in ducts (A)</th>
<th>In air in shade (A)</th>
<th>In air in sun (A)</th>
<th>In troughing in sun (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>3</td>
<td>175</td>
<td>150</td>
<td>180</td>
<td>160</td>
<td>120</td>
</tr>
<tr>
<td>95</td>
<td>3</td>
<td>270</td>
<td>240</td>
<td>275</td>
<td>230</td>
<td>200</td>
</tr>
<tr>
<td>150</td>
<td>3</td>
<td>345</td>
<td>305</td>
<td>360</td>
<td>310</td>
<td>260</td>
</tr>
<tr>
<td>240</td>
<td>1</td>
<td>475</td>
<td>410</td>
<td>560</td>
<td>420</td>
<td>340</td>
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<tr>
<td>240</td>
<td>3</td>
<td>440</td>
<td>385</td>
<td>480</td>
<td>390</td>
<td>340</td>
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<tr>
<td>300</td>
<td>1</td>
<td>515</td>
<td>440</td>
<td>628</td>
<td>520</td>
<td>352</td>
</tr>
</tbody>
</table>

### Table 5 – 33 kV cables with TR-XLPE insulation – Continuous current ratings

<table>
<thead>
<tr>
<th>Conductor area mm²</th>
<th>No of cores</th>
<th>Direct buried (A)</th>
<th>Buried in ducts (A)</th>
<th>In air in shade (A)</th>
<th>In air in sun (A)</th>
<th>In troughing in sun (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>1</td>
<td>335</td>
<td>310</td>
<td>380</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>150</td>
<td>3</td>
<td>340</td>
<td>305</td>
<td>370</td>
<td>310</td>
<td>260</td>
</tr>
<tr>
<td>300</td>
<td>1</td>
<td>530</td>
<td>460</td>
<td>650</td>
<td>500</td>
<td>400</td>
</tr>
<tr>
<td>300</td>
<td>3</td>
<td>485</td>
<td>430</td>
<td>550</td>
<td>470</td>
<td>375</td>
</tr>
<tr>
<td>400</td>
<td>1</td>
<td>590</td>
<td>520</td>
<td>740</td>
<td>590</td>
<td>445</td>
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<tr>
<td>500</td>
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<td>650</td>
<td>570</td>
<td>830</td>
<td>600</td>
<td>490</td>
</tr>
<tr>
<td>630</td>
<td>1</td>
<td>720</td>
<td>615</td>
<td>930</td>
<td>665</td>
<td>-</td>
</tr>
</tbody>
</table>

### Table 6 – 66 kV cables with XLPE insulation – Continuous current ratings

<table>
<thead>
<tr>
<th>Conductor area mm²</th>
<th>No of cores</th>
<th>Direct buried (A)</th>
<th>Buried in ducts (A)</th>
<th>In air in shade (A)</th>
<th>In air in sun (A)</th>
<th>In troughing in sun (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>95</td>
<td>1</td>
<td>300</td>
<td>277</td>
<td>346</td>
<td>289</td>
<td>207</td>
</tr>
<tr>
<td>150</td>
<td>1</td>
<td>375</td>
<td>338</td>
<td>444</td>
<td>371</td>
<td>265</td>
</tr>
</tbody>
</table>

### 11. Manufacturing process

The conductor screen, insulation and insulation screen shall be manufactured utilising a continuous triple extrusion line, either Continuous Catenary Vulcanisation (CCV) or Vertical Continuous Vulcanisation (VCV), and dry curing technique. For 66 kV cables VCV is preferred.

None of the three extruded insulation layers shall be repaired or jointed during manufacture.
12. Cables for use in tunnels or underground stations

Cables for use in tunnels or underground stations shall have a low smoke, low toxicity, halogen free (LSOH) non-metallic oversheath including a flame retardant outer sheath suitable for installation in damp situations.

The cable itself shall be to classification RHE in accordance with AS/NZS 4507 Cables – Classification of characteristics when exposed to fire.

The flame retardant outer sheath shall be of a material that provides adequate protection against mechanical damage for the designed construction methodology of the project.

The oversheath assembly shall not contain polyvinyl chloride (PVC) or other halogen-producing materials.

The oversheath assembly shall comprise a high density polyethylene (HDPE) inner sheath followed by flame retardant outer sheath.

For three core cables without metal sheath, a layer of LSOH bedding shall be provided between the core assembly and the HDPE sheath so as to comply with the intent of the provision of AS/NZS 1429.1.

Refer to ESC 340 Tunnels for the definition of tunnels for the purpose of fire safety.

13. Tests

Cables shall have been tested in accordance with AS/NZS 1429.1 or AS/NZS 1429.2 as appropriate to the voltage rating.

All tests shall be done by laboratories with accreditation by the National Association of Testing Authorities (NATA), Australia, or equivalent accreditation approved by the ASA.

13.1. Type tests

Type tests shall be performed on cables manufactured in the plant and on the insulation and sheath materials.

Results of type tests shall be assessed by the relevant AEO, and approved by the ASA as part of the cable type approval process.

13.1.1. Cable

Type tests shall be performed, or type test certificates provided, in accordance with AS/NZS 1429.1 or AS/NZS 1429.2, as applicable to voltage rating.
Type test certificates shall be supplied by the manufacturer for tests performed on cables manufactured in the plant. Cable details and performance figures are specified in Section 14.3.

13.1.2. Insulation and sheath materials

Type test certificates shall be provided to demonstrate compliance with AS/NZS 3808 Insulating and sheathing materials for electric cables and shall be supplied by the manufacturer.

13.2. Routine tests

Routine tests shall be performed on the cable in accordance with AS/NZS 1429.1 or AS/NZS 1429.2 applied to the relevant voltage rating.

13.3. Sample tests

Sample tests shall be performed on the cable in accordance with AS/NZS 1429.1 or AS/NZS 1429.2 applied to the relevant voltage rating.

13.4. Tests certificates and qualification test report

A qualification test report and test certificates covering all type, sample and routine tests in accordance with AS/NZS 1429.1 or AS/NZS 1429.2, as applicable to voltage rating shall be provided by the supplier and accepted by the relevant AEO. The test report and certificates shall be supplied, in duplicate and electronically, and shall be in English.

14. Data set associated with the cables

Product data shall be obtained from the manufacturer for each cable type and size. The data shall be maintained by the custodian of the asset.

The following data shall be obtained:

- technical drawings
- test results
- cable construction details and performance data

14.1. Technical drawings

The manufacturer shall provide a detailed to scale drawing showing the cross section of the cable and identifying the individual layers of the cable and including a detailed description of the layers with associated dimension adjacent.
14.2. **Test results**

Test results shall be supplied by the supplier in accordance with AS/NZS 1429.1 or AS/NZS 1429.2, as applicable to voltage rating.

Qualification test report and test certificates are required.

14.3. **Cable construction details and performance figures**

The cable details and performance figures to be obtained from the manufacturer for each cable type and size includes the following:

- cable type
- nominal voltage rating (kV)
- conductor
  - conductor material (copper)
  - conductor stranding (no/mm)
  - compacted or compressed
  - overall conductor diameter (mm)
  - cross sectional area (mm²)
- insulation material and supplier
- radial thickness of insulation, excluding semi-conducting layers (mm)
- details of conductor semi-conducting layer and supplier
- details of insulation semi-conducting layer and supplier
- details of line and curing method
- details of longitudinal water blocking system, where specified
- details of metallic moisture barrier, where specified
- details of metallic screen
  - wires stranding (no/mm)
  - cross sectional area (mm²)
  - approximate coverage (%)
- materials and minimum thickness of oversheath, including flame retardant sheath if applicable
- cable emissivity
cable overall diameter (mm)
cable mass (kg/100 m)
minimum bending radius adjacent to joints and terminations (m)
maximum allowable pulling tension via stockinette (newtons)
cable BIL (kV)
maximum conductor operating temperature
  o normal (°C)
  o emergency – 2 hour (°C)
  o short circuit (°C)
maximum dc resistance of conductor of completed cable at 20 °C (ohms/km)
positive sequence impedance of completed cable including resistive and reactive components:
  o at 20 °C (ohms/km)
  o at maximum operating temperature (ohms/km)
zero sequence impedance of completed cable with metallic screen return, including resistive and reactive components:
  o at 20 °C (ohms/km)
  o at maximum operating temperature (ohms/km)
core to screen capacitance (µF/km)
minimum insulation resistance (conductor to screen) at 20 °C (MΩ/km)
minimum insulation resistance for metallic screen at 20 °C (MΩ/km)
maximum continuous current rating with screens solidly bonded both ends, ambient air temperature 40 °C, depth of laying 0.8 m, ambient soil temperature 25 °C and soil thermal resistivity 1.2 °C.m/watt, (for single core cables: in trefoil, touching):
  o buried direct (amps)
  o buried in ducts (amps)
  o in air, at ambient temperature of 40 °C (amps)
two-hour emergency current rating, with cables at normal maximum operating temperature at the time of emergency:
  o buried direct (amps)
- buried in ducts (amps)
- in air, at ambient temperature of 40 °C (amps)

- maximum short circuit rating for one second:
  - core (amps)
  - screen (amps)

- cable losses at full load (kw/km)
Appendix A  Ratings for existing cables - not to be used in new installations

The existing TfNSW HV distribution network contains various cable types and sizes that are not permitted to be used for new installations. The continuous current ratings for these cables are included in Table 7 and Table 8 for information purposes only.

Table 7 – Existing 11 kV cables not to be used for new installations – Continuous current ratings

<table>
<thead>
<tr>
<th>Insulation</th>
<th>Cond area mm²</th>
<th>No of cores</th>
<th>Direct buried (A)</th>
<th>Buried in ducts (A)</th>
<th>In air in shade (A)</th>
<th>In air in sun (A)</th>
<th>In troughing in sun (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>XLPE</td>
<td>35</td>
<td>3</td>
<td>165</td>
<td>145</td>
<td>160</td>
<td>150</td>
<td>120</td>
</tr>
<tr>
<td>XLPE</td>
<td>50</td>
<td>1</td>
<td>205</td>
<td>175</td>
<td>215</td>
<td>180</td>
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<tr>
<td>XLPE</td>
<td>50</td>
<td>3</td>
<td>195</td>
<td>170</td>
<td>190</td>
<td>175</td>
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<td>XLPE</td>
<td>95</td>
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<td>290</td>
<td>250</td>
<td>320</td>
<td>250</td>
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<tr>
<td>XLPE</td>
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<td>320</td>
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<td>3</td>
<td>90</td>
<td>80</td>
<td>75</td>
<td>75</td>
<td>65</td>
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<td>170</td>
<td>155</td>
<td>160</td>
<td>155</td>
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<td>160</td>
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<td>140</td>
<td>140</td>
<td>120</td>
</tr>
<tr>
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<td>95</td>
<td>1</td>
<td>250</td>
<td>255</td>
<td>245</td>
<td>250</td>
<td>180</td>
</tr>
<tr>
<td>Paper</td>
<td>95</td>
<td>3</td>
<td>240</td>
<td>205</td>
<td>210</td>
<td>210</td>
<td>180</td>
</tr>
<tr>
<td>Paper</td>
<td>150</td>
<td>1</td>
<td>325</td>
<td>285</td>
<td>325</td>
<td>290</td>
<td>230</td>
</tr>
<tr>
<td>Paper</td>
<td>150</td>
<td>3</td>
<td>305</td>
<td>255</td>
<td>280</td>
<td>265</td>
<td>230</td>
</tr>
</tbody>
</table>
Table 8 - Existing 33 kV cables not to be used for new installations – Continuous current ratings

<table>
<thead>
<tr>
<th>Insulation</th>
<th>Cond area mm²</th>
<th>No of cores</th>
<th>Direct buried (A)</th>
<th>Buried in ducts (A)</th>
<th>In air in shade (A)</th>
<th>In air in sun (A)</th>
<th>In troughing in sun (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>XLPE</td>
<td>50</td>
<td>1</td>
<td>205</td>
<td>180</td>
<td>225</td>
<td>180</td>
<td>145</td>
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<tr>
<td>XLPE</td>
<td>50</td>
<td>3</td>
<td>190</td>
<td>170</td>
<td>195</td>
<td>170</td>
<td>145</td>
</tr>
<tr>
<td>XLPE</td>
<td>95</td>
<td>1</td>
<td>290</td>
<td>255</td>
<td>330</td>
<td>255</td>
<td>-</td>
</tr>
<tr>
<td>XLPE</td>
<td>95</td>
<td>3</td>
<td>270</td>
<td>240</td>
<td>280</td>
<td>240</td>
<td>205</td>
</tr>
<tr>
<td>XLPE</td>
<td>240</td>
<td>1</td>
<td>475</td>
<td>415</td>
<td>570</td>
<td>440</td>
<td>355</td>
</tr>
<tr>
<td>XLPE</td>
<td>240</td>
<td>3</td>
<td>440</td>
<td>390</td>
<td>485</td>
<td>425</td>
<td>340</td>
</tr>
<tr>
<td>XLPE</td>
<td>400</td>
<td>3</td>
<td>540</td>
<td>480</td>
<td>620</td>
<td>530</td>
<td>-</td>
</tr>
<tr>
<td>Paper (HSL)</td>
<td>0.2 in²</td>
<td>3</td>
<td>255</td>
<td>225</td>
<td>210</td>
<td>210</td>
<td>140</td>
</tr>
<tr>
<td>Paper (HSL)</td>
<td>0.25 in²</td>
<td>3</td>
<td>285</td>
<td>255</td>
<td>250</td>
<td>235</td>
<td>155</td>
</tr>
<tr>
<td>Paper / Gas</td>
<td>0.25 in²</td>
<td>3</td>
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Appendix B  Packaging requirements

The cable should be wound onto wooden or steel drums and prepared for delivery – all in accordance with the requirements of AS/NZS 1429.1 or AS/NZS 1429.2, as appropriate.

Wooden drums are preferred; however, steel drums may be necessary in the following situations:

- where additional mechanical protection is required; for example, where cable is delivered from overseas inside a shipping container
- where cable will be stored in the open for extended periods; for example, spare stock
- where cable will be 'paid out' utilising a motorised cradle, or other device requiring smooth drum rims

The cable should be protected by wooden battens or approved equivalent. Corrugated plastic materials are not acceptable.

The order number, length of cable, weight, size and type of cable should be painted on each drum.

Consideration should be made by the purchaser on the construction and storage methodology, including constraints on access routes, and capacities of plant and off loading facilities. The following should be specified by the purchaser:

- cable drum material (wood or steel)
- maximum diameter and width of cable drums
- shape and dimension of spindle hole
- maximum gross weight of each cable drum
- ownership of cable drums (supplier or purchaser)
Appendix C  Guide to information requirements for request for tender

C.1. Information to be supplied to tenderers

For each type and conductor size of cable required, the following information should be provided to tenderers:

• voltage rating
• conductor size (mm²)
• insulation
• cable construction (see Section 9)
• flame retardant oversheath requirement (see Section 12)
• total length requirement
• preferred cable length per drum
• delivery location
• delivery date
• details of cable drums, total weight limitations and (if it matters) whether wooden or steel drums (see Appendix B)
• a statement regarding cable drum ownership arrangement (see Appendix B)
• requirement for a pulling eye, fitted to the conductor, on the cable end (if needed)
• a statement stipulating that type testing and routine testing will be at the suppliers cost and that the purchaser reserves the right to witness tests carried out
• a statement stipulating that the purchaser reserves the right to conduct audits of the manufacturing plant
• a statement stipulating that the purchaser reserves the right to inspect the cables at any time during the manufacturing process

C.2. Information to be supplied by tenderers

For each type and conductor size of cable required, the following information should be provided by tenderers:

• cable construction details and performance figures (see Section 14.3)
• drawings (see Section 14.1)
• type test certificates and qualification test report
• compatibility of cable with ASA type approved cable accessories
• if the cables are intended for manufacture in a plant not previously inspected by the purchaser, then the tender price should include travel and accommodation costs for a purchaser representative to inspect the plant
• details of manufacturer’s quality management system
• proposed delivery schedule

C.2.1 Cable production plan
A cable production plan, where required by the purchaser, should be provided to show milestones (dates and times commencing from receipt of order) of all intermediate processes (including manufacture and testing) through to cable delivery.

C.2.2 Test certificates
Copies of certified test certificates and qualification test reports covering type tests, routine tests and sample tests should be provided prior to delivery of the cables.