TS 03683:1.0

T HR EL 04001 SP

Specification

1500 V DC Metal Enclosed Switchgear

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Document history

Revision	Effective date	Summary of changes
1.0	25 June 2018	First issue with designation T HR EL 04001 SP.
1.0	29 October 2025	Renumbered as TS 03683:1.0. Version number recommenced in line with new designation. Changes to previous content include conversion of the standard to PAM format and style, replacement of TAHE organisation roles and processes with those applicable to the current TfNSW organisational context, incorporation of technical note TN 011:2020, addition of the rated service current for the bus-section DCCB, inclusion of requirements for 1500 V dc positive bus-section cables to be connected to the switchgear frame leakage scheme, inclusion of 1500 V dc harmonic filter requirements, and inclusion of requirements for 1500 V dc metro.

Preface

This specification is a first issue as TS 03683 and supersedes T HR EL 04001 SP *Heavy Rail Traction System – 1500 V DC Metal Enclosed Switchgear*, version 1.0.

This document provides requirements for the procurement of 1500 V dc metal enclosed indoor switchgear suitable for use in the TfNSW metropolitan heavy rail network and 1500 V dc metro 1500 V dc traction system.

Further background information on the TfNSW metropolitan heavy rail network 1500 V dc traction system and general information on relevant electrical infrastructure and assets is detailed in TS 03739.

All information required to ensure that the switchgear is electrically suitable for the TfNSW metropolitan heavy rail network and 1500 V dc metro electrical network is contained in this document or referenced by this document.

The changes to previous content in T HR EL 04001 SP are as follows:

- issued under Prioritisation and Asset Management (PAM) designation TS 03683:1.0
- conversion of the document to PAM format and style
- replacement of TAHE organisation roles and processes with those applicable to the current TfNSW organisational context
- incorporation of technical note TN 011:2020
- addition of the rated service current for the bus-section DCCB
- inclusion of requirements for 1500 V dc positive bus-section cables to be connected to the switchgear frame leakage scheme
- inclusion of 1500 V dc harmonic filter requirements
- inclusion of requirements for 1500 V dc metro.

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1 Scope

This specification covers the whole-of-life performance and technical requirements for 1500 V dc metal enclosed switchgear containing SCADA controlled DCCBs incorporating rail connecting equipment suitable for remote operation.

2 Application

The requirements of this document apply to procurement of 1500 V dc indoor metal enclosed switchgear in a traction substation or sectioning hut used on the TfNSW metropolitan heavy rail network and on the 1500 V dc metro lines within the MRA.

The requirements of this document do not apply to the operation or maintenance of existing metal enclosed 1500 V dc indoor switchgear currently in service.

For clarification of any requirements in this document contact PAM.

3 Referenced documents

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

International standards

EN 50121-5 *Railway applications – Electromagnetic compatibility – Part 5: Emission and immunity of fixed power supply installations and apparatus*

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

EN 50123-1 *Railway applications – Fixed installations dc switchgear – Part 1: General*

EN 50123-1:2003 *Railway applications – Fixed installations – D.C. switchgear – Part 1: General*

EN 50123-2 *Railway Applications – Fixed Installations – D.C. Switchgear – Part 2: D.C. Circuit Breakers*

EN 50123-2:2003 *Railway Applications – Fixed Installations – D.C. Switchgear – Part 2: D.C. Circuit Breakers*

EN 50123-3:2003 *Railway applications – Fixed installations – D.C. switchgear – Part 3: Indoor d.c. disconnectors, switch-disconnectors and earthing switches*

EN 50123-6 *Railway applications – Fixed installations – D.C. switchgear – Part 6: D.C. switchgear assemblies*

EN 50123-6: 2003 *Railway applications – Fixed installations – D.C. switchgear – Part 6: D.C. switchgear assemblies*

EN 50123-7-1:2003 *Railway Applications – Fixed Installations – D.C. Switchgear – Part 7-1: Measurement, Control and Protection Devices for Specific Use in D.C. Traction Systems – Application guide*

EN 50123-7-2 *Railway Applications – Fixed Installations – D.C. Switchgear – Part 7-2: Measurement, Control and Protection Devices for Specific Use in D.C. Traction Systems – Isolating Current Transducers and Other Current Measuring Devices*

EN 50123-7-3 *Railway Applications – Fixed Installations – D.C. Switchgear – Part 7-3: Measurement, Control and Protection Devices for Specific Use in D.C. Traction Systems – Isolating Voltage Transducers and Other Voltage Measuring Devices*

EN 50163 *Railway applications – Supply voltages of traction systems*

IEC 60051-1 *Direct acting indicating analogue electrical measuring instruments and their accessories – Part 1: Definitions and general requirements common to all parts*

IEC 60051-2 *Direct acting indicating analogue electrical measuring instruments and their accessories – Part 2: Special requirements for ammeters and voltmeters*

IEC 60051-3 *Direct acting indicating analogue electrical measuring instruments and their accessories – Part 3: Special requirements for wattmeters and varmeters*

IEC 60051-7 *Direct acting indicating analogue electrical measuring instruments and their accessories – Part 7: Special requirements for multi-function instruments*

IEC 60051-8 *Direct acting indicating analogue electrical measuring instruments and their accessories – Part 8: Special requirements for accessories*

IEC 60051-9 *Direct acting indicating analogue electrical measuring instruments and their accessories – Part 9: Recommended test methods*

IEC 60529 *Degrees of protection provided by enclosures (IP Code)*

Australian standards

AS 60529 *Degrees of protection provided by enclosures (IP Code) (IEC 60529:1989 (ED. 2.2) MOD)*

AS 61508 (all parts) *Functional safety of electrical/electronic/programmable electronic safety-related systems*

AS 62271.200 *High-voltage switchgear and control gear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV (IEC 62271-200:2011/COR1:215, MOD)*

AS IEC 60300 (all parts) *Dependability management*

AS/NZS 3000 *Electrical installations (known as the Australian/New Zealand Wiring Rules)*

Transport for NSW standards

TS 00011 *Common Requirements for Electrical Power Equipment*

TS 01505 (T MU AM 01001 ST) *Life Cycle Costing*

TS 01547.1 (T MU MD 00006 ST) *Engineering Drawings and CAD Requirements*

TS 03735 (T HR EL 19001 ST) *Protection System Requirements for the 1500 V DC Network*

TS 03739 (T HR EL 00001 TI) *RailCorp Electrical System General Description*

TS 03742 (T HR EL 00002 PR) *Electrical Power Equipment – Integrated Support Requirements*

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

TS 03821 (T HR EL 03001 ST) *Controls and Protection for 1500 V dc Rectification Equipment*

TS 03865 *Electrical SCADA Interface Requirements*

TS 03866 *Electrical SCADA System Remote Terminal Unit*

TS 03869 *Lightning Protection and Insulation Coordination*

TS 03872 (T HR EL 90002 ST) *Heavy Rail Traction System – Voltage Ratings*

TS 03873 (T HR EL 90003 ST) *Heavy Rail Traction System – Current ratings of 1500 V dc Equipment*

TS 04978 (T MU HF 00001 ST) *Human Factors Integration – General Requirements*

TS 04981 (T MU MD 20001 ST) *System Safety Standard for New or Altered Assets*

TS 04990 (T MU SY 10010 ST) *Cybersecurity for IACS – Overview*

TS 06178 (T MU MD 00005 GU) *Type Approval of Products*

TS 01515.1 *Asset Information – Part 1: Management of Asset Information*

Transport for NSW drawings

TS 00272 (EL 0588757) *1500 V Feeder DCCB BHF-30B – schematic diagram* (This document is not publicly available. To obtain access email standards@transport.nsw.gov.au)

TS 00273 (EL 0588758) *1500 V Feeder DCCB BHF-30B – wiring diagram* (This document is not publicly available. To obtain access email standards@transport.nsw.gov.au)

Other referenced documents

Sydney Trains, 2022, *Electrical Network Safety Rules,* PR D 78000, Rail Safe

Note: The document PR D 78000 is available from the RailSafe website.

4 Terms, definitions and abbreviations

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

ac alternating current

ACCB alternating current circuit breaker

COTS commercial off the shelf

DAOL direct acting overload

dc direct current

DCCB direct current circuit breaker

dc feeder refers to the complete 1500 V dc section connected to the line DCCB which consists of the overhead wiring and the connected 1500 V dc positive cables

EMC electromagnetic capability

ESO electrical system operator

FAT factory acceptance test

high setting the effective overcurrent trip setting of the DCCB (protection relay setting) when the signal to increase the setting is active

HV high voltage, a voltage exceeding 1000 V ac or 1500 V dc

IED intelligent electronic device

L/O locked out (state)

low setting the normal overcurrent trip setting of the DCCB (protection relay setting)

MRA metropolitan rail area

OC overcurrent

OHW overhead wiring

PAM Prioritisation and Asset Management

rail connecting switch both a dc disconnector and a rail connecting switch. A mechanical switching device, which provides, in the TO RAIL position, for safety reasons, an isolating distance in accordance with specified requirements. It is also used to connect parts of the circuit to the traction return rail, capable of withstanding for a specified time, currents under abnormal conditions such as those of short-circuit, as well as traction return current in some circumstances, but not required to carry currents under normal conditions of the circuit.

RAMS reliability, availability, maintainability and safety

reclose a close action initiated by the auto reclose controls on the DCCB

RTU remote terminal unit

SAT site acceptance test

SCADA supervisory control and data acquisition

SIL safety integrity level

TAO Technically Assured Organisation

TfNSW Transport for NSW

5 Transport for NSW type approval

All switchgear procured in accordance with this document requires type approval by TfNSW prior to being connected to TfNSW metropolitan heavy rail electrical network or 1500 V dc metro electrical network.

DC protection relays shall have individual type approval in accordance with TS 06178.

Refer to TS 06178 for information on the TfNSW process for type approval.

6 Overview

6.1 General

The 1500 V dc switchgear shall consist of 1500 V dc positive and negative busbar, fully withdrawable trip-free DCCBs, fixed two-position disconnector and associated control and protection equipment. The switchgear shall be of the metal enclosed compartmented type.

A 1500 V dc harmonic filter with 1500 V dc busbar surge arrester shall also be provided as part of the switchgear when specified.

The two-position disconnector shall be housed in individual compartments which are incorporated into the general switchgear enclosure.

When specified 1500 V dc bypass switches shall be provided as part of the switchgear for metro.

The switchgear shall be fully type tested, both as individual components and as a complete assembly.

6.2 Protection principles of the direct current electric traction supply system

The function of the 1500 V dc protection system shall provide protection in the event of fault conditions and abnormal operations. This protection is provided by monitoring certain process values such as current, voltage and temperature and by the initiation of interventions, such as tripping of circuit breakers.

The main objectives for protection systems are as follows:

- continuation of service and performance of the electric traction supply system and minimising the disturbance to operations as far as practicable
- limitation of the impact and damage to the affected equipment
- avoidance of cascading effects and expanding to other network areas
- minimisation of arcing effects and energy released during faults
- contribution to the protection of persons against indirect electric shock.

Electrical safety of the electric traction system shall be ensured by satisfying a wide range of requirements including those in EN 50122-1 and EN 50122-3.

The protection system is not intended to prevent the risk of electric shock due to direct contact with live equipment. See Section 13.13 for detailed requirements of the 1500 V dc protection.

6.3 Rolling stock interface

The system to be protected within the scope of this document is the electric traction supply system. Protection of electric rolling stock against faults downstream of the rolling stock high speed circuit breaker is not a primary function of the protection system of the traction supply system metal-clad switchgear.

7 Functional requirements for 1500 V dc metal enclosed switchgear

The 1500 V dc switchgear shall provide for the following:

- disconnection, isolation and connection of 1500 V dc OHW feeders to the 1500 V positive dc busbar
- disconnection, isolation and connection of 1500 V dc OHW feeders to the negative (traction return busbar)
- disconnection, isolation and connection of 1500 V dc rectifiers to the 1500 V dc positive busbar
- isolation of a section of 1500 V dc positive busbar within a switchboard
- disconnection, isolation and connection of the 1500 V dc surge arrester to the 1500 V dc positive busbar
- disconnection, isolation and connection of 1500 V dc energy or voltage support equipment to the 1500 V dc positive busbar
- connection of 1500 V dc positive busbar sections to earth

- provision of a 1500 V dc harmonic filter in traction substations
- protection and SCADA control for 1500 V dc OHW feeders, rectifier dc circuits, harmonic filters, 1500 V dc energy/voltage support equipment and negative connections.

8 Switchgear requirements

8.1 General

Table 1 provides details of general requirements for 1500 V dc metal enclosed switchgear.

Table 1 – Switchgear general requirements

Parameter	Designation
Switchgear type	Metal enclosed – compartmented
Functional units	• rectifier DCCBs • line DCCBs with two position disconnector • bus-section DCCBs • bypass switch (only applicable to metro) • harmonic filter and busbar surge arrester panel • energy and voltage support equipment DCCBs
Switchgear insulation medium	Air insulated
Class	Indoor
IP rating (minimum)	• IP2X (in accordance with table 1 of EN 50123-6:2003) • IP3X for the LV compartment (in accordance with AS 60529 or equivalent)
IP rating (minimum, applies to metro) (in accordance with AS 60529 and IEC 60529)	IP42
Vibration	In accordance with table B.1 of EN 50123-1:2003
Possible extension to switchgear	Both sides
Material restrictions	Asbestos is not allowed

The switchgear shall be designed and manufactured in accordance with the standards in Table 2 and Table 3 along with the specific class and classification.

Table 2 – Switchgear standards

Parameter	Designation
DCCB	EN 50123-2
Two position disconnector	EN 50123-3

Parameter	Designation
General	• EN 50123-1 • EN 50123-6 • EN 50123-7-1 • EN 50123-7-2 • EN 50123-7-3 • EN 50121-5 • TS 03744 (see note 1) • TS 03873 • TS 03872

Note 1: This document states the maximum ambient temperatures, and they differ from EN 50123-1:2003 annex B. Where the switchgear does not meet the temperature requirements of TS 03744, then applicable de-rating factors shall be provided by the manufacturer.

Table 3 – Switchgear common ratings

Parameter	Standard	Rating
Nominal voltage (Un)	EN 50163	1500 V dc
Rated voltage (U_{Ne})	Table 1 of EN 50123-1:2003	1800 V dc
Rated insulation voltage (U_{Nm})	Table 1 of EN 50123-1:2003	3000 V dc
Rated impulse voltage to earth (U_{NiA})	Table 1 of EN 50123-1:2003	15 kV peak (1.2/50 µs)
Rated impulse voltage across isolating distance (U_{NiB})	Table 1 of EN 50123-1:2003	18 kV peak (1.2/50 µs)
Power frequency withstand voltage to earth (U_{aA})	Table 1 of EN 50123-1:2003	6.9 kV (50 Hz for 1 min)
Internal arc classification	EN 50123-6 AS 62271.200	See Section 12
Electrical clearance: 1500 V dc to earth creepage distance	 EN 50123-1:2003 table 1 Material group 1 in table D2 of EN 50123-1:2003	 ≥ 27 mm ≥ 75 mm (see note 1)

Note 1: This is the preferred value in accordance with material group 1 in table D2 of EN 50123-1:2003. The minimum value shall be at least equal to the value for across the isolating distance in accordance with EN 50123-1.

Additional relevant information shall be supplied along with the request for tender as detailed in Appendix G.

Typical switchgear configurations are detailed in Appendix B.

8.2 1500 V dc positive busbar

The 1500 V dc positive busbar shall meet the common ratings in Table 3 and those in Table 4.

Table 4 – 1500 V dc positive busbar requirements

Parameter	Standard	Rating
Rated system current – busbar (I_{Ne}) (see note 1)	TS 03873	≥ 4000 A (location with single rectifier service) or ≥ 6400 A (location with two rectifiers in service)
Rated system current – busbar (I_{Ne}) (applies to metro)	N/A	≥ 9000 A
Rated short circuit current (I_{Nss})	TS 03873 EN 50123-6	≥ 75 kA
Rated short-time withstand current (I_{Ncw})	TS 03873 EN 50123-6	≥ 75 kA for 250 ms

Note 1: The overload conditions specified in TS 03873 shall apply to the busbar rating in addition to the continuous rating.

8.3 Direct current circuit breaker

The DCCB shall meet the common ratings in Table 3 and those specified in Table 5 and Table 6.

Table 5 – DCCB parameters

Parameter	Designation
Main device type	Withdrawable
Use in the system	• line (L) • rectifier (R) • bus-section (I) • energy/voltage support equipment (L_V)
Breaking characteristic (class designation)	High speed current limiting circuit breaker (H)
Current interruption direction (heavy rail): • line, rectifier, energy/voltage support • bus-section	• unidirectional with series release (U_1) • bidirectional (B)

Parameter	Designation
Current interruption direction (metro): • line, rectifier, bus-section, energy/voltage support	• bidirectional (B)
Provision of an enclosure	Separate enclosure (P)
Duties and test duty cycle	In accordance with table 2 and table 3 of EN 50123-2:2003. Test duty cycle one applicable for line and bus-section DCCBs
Interruption medium	• air • semiconductor (see note 1)
Principal of operation	• trip free • DAOL shall be integral to the DCCB operating mechanism and not initiated by a protection relay

Note 1: Where the DCCB interruption is implemented with semiconductors then the switchgear configuration shall be assessed for compliance with Sydney Trains and metro electrical network safety requirements (ENSR) requirements.

Table 6 – DCCB ratings

Parameter	Standard	Rating
Maximum arc voltage (Ûarc)	N/A	≤ 3500 V dc and rated impulse withstand voltage of the equipment
Rated service current (I_{Ne})	EN 50123-2	≥ 4000 A (line DCCB) see note 1 ≥ 6300 A (rectifier DCCB) see note 1 See note 2 and note 3 for bus-section DCCB
Power frequency withstand voltage across the isolating distance (UaB)	Table 1 of EN 50123-1:2003	8.3 kV (50 Hz for 1 min)
Electrical clearance across the isolating distance:	EN 50123-1:2003 table 1	≥ 32 mm (see note 4)
Rated track time constant (T_{Nc})	EN 50123-2	63 ms
Rated short circuit current (I_{Nss})	TS 03873 EN 50123-2	≥ 75 kA
Protection and control supply voltage	TS 00011	125 V dc
Auxiliary contacts and circuits	N/A	2 × NC and 2 × NO contacts rated at 125 V dc in addition to contacts required for operation and control by the manufacturer for operation of the DCCB

Parameter	Standard	Rating
Electrical endurance operating cycles	EN 50123-2	200 (line DCCB) 100 (rectifier, bus-section DCCB)
Mechanical endurance	EN 50123-2	10,000 (line DCCB) 4000 (rectifier, bus-section DCCB)

Note 1: Line DCCB, bus-section and rectifier DCCB current ratings shall have overload ratings in accordance with TS 03873.

Note 2: The rated service current of a bus-section DCCB should as a minimum be equal to the nominal rated system current of the busbar rating in accordance with Table 4.

Note 3. A lower rating may be proposed subject to network modelling and approval of PAM.

Note 4: This is applicable to DCCB with air as the interruption medium.

8.4 Positive or negative busbar disconnector

The disconnector shall be integral to the switchgear. It shall meet the common ratings in Table 3 and those specified in Table 7 and Table 8.

Table 7 – Two position – positive or negative busbar disconnector parameters

Parameter	Designation
Type of disconnector	Two position – positive or negative busbar disconnector
Number of poles	Single pole
Number of positions	Two positions (CLOSED and TO RAIL)
Provision of enclosure	Integral to the switchgear
Class of use	Category 1 (close and open at no-load) (see note 1)
Electrically operated or manual operation	Both
Confirmation of switch status	Indicator

Note 1: No-load rating for open and close actions as the two-position disconnector is in series with the DCCB.

Table 8 – Two-position – positive or negative busbar disconnector ratings

Parameter	Standard	Rating
Rated service current (I_{Ne})	EN 50123-1	≥ 4000 A (see note 1)
Rated short time withstand current (I_{Ncw})	EN 50123-1 TS 03873	75 kA for 250 ms

Parameter	Standard	Rating
Electrical clearance across the isolating distance:	EN 50123-1:2003 table 1	≥ 32 mm
Control and motor supply voltage	TS 00011	125 V dc
Auxiliary contacts and circuits	N/A	2 × NC and 2 × NO contacts rated at 125 V dc in addition to contacts required for operation and control
Rated service current (I_{Ne}) (only applicable to metro)	N/A	3000 A (note 2)

Note 1: The overload conditions in TS 03873 apply to the two-position disconnector rating.

Note 2: Metro by-pass switches are motorised operable on-load.

The rated service current applicable to metro is specified in Table 9.

Table 9 – Three-position – positive or negative busbar disconnector ratings (only applicable to metro)

Parameter	Standard	Rating
Rated service current (I_{Ne})	EN 50123-1	4000 A (see note 1)

Note 1: The disconnecting switch for metro shall be a motorised 3-position no load switch.

8.5 Harmonic filter and 1500 V dc positive busbar surge arrester

Where specified, a harmonic filter and surge arrester panel shall be used to facilitate the connection of a 1500 V dc harmonic filter and associated surge arrester to the 1500 V dc positive busbar.

The harmonic filter and surge arrester components shall be mounted on the same DCCB truck as used for the rectifier and line panels. There is no requirement for a DCCB. The isolation from the 1500 V dc positive busbar shall be achieved with a switch.

The harmonic filter shall filter harmonics at 600 Hz and 1200 Hz corresponding with two rectifiers in service, both operating at 100% rated load. The harmonic filter shall reduce the level of harmonics by a minimum factor of 10.

The harmonic filter shall have the following:

- an open and close switch with corresponding indications (LED indication)
- an interlock so that the capacitors are shorted when the filter is racked out
- an ammeter and a voltmeter for each leg of the filter

- an individual fuse for each leg of the filter as well as a main protection fuse
- a method to safely dissipate the capacitors
- a surge arrestor to protect the filter.

9 Electrical clearances

The minimum required electrical clearances are specified in Table 3.

In addition, the following requirements shall also be complied with:

- equipment connected to the 1500 V dc circuit within the switchgear shall be segregated from all other control and auxiliary equipment operating at lower voltages by suitable barriers or a physical separation of at least 50 mm
- all conductors carrying 1500 V dc shall be physically segregated from voltages at lower potential (including ‘earth’) by a distance that prevents any flash-over from high to low voltage conductors
- all 1500 V dc wiring shall be harnessed separately from other control and auxiliary wiring
- all equipment connected to the 1500 V dc circuit, such as coils and resistors, shall be adequately segregated and contain protection against flash-over
- all low voltage wiring that is located in any compartment containing 1500 V dc conductors or equipment shall be enclosed in conduit or similar.

10 Earthing

An earthing busbar extending the whole length of the switchgear in accordance with EN 50123-6 shall be provided. The earthing of the switchgear shall be through a frame leakage scheme in accordance with Section 14.6.

The earth bar shall have the facility to connect two 70 mm^2 cables which are connected to the traction substation earth system.

The traction substation earth cables should be able to be connected at both ends of the switchgear earth bar.

11 1500 V dc surge arresters for line panels

The line panels shall have the facility to install a 1500 V dc surge arrester if required between the outgoing 1500 V dc positive cable busbar and the substation earth.

Refer to TS 03869 for details on the 1500 V dc surge arresters and their application.

12 Switchgear internal arc rating and venting

The switchgear shall comply with EN 50123-6 requirements for internal arcing.

The switchgear shall be designed to ensure that the arc venting associated with internal faults does not endanger persons in the vicinity of the switchgear in normal operating conditions and with the switchgear in the normal service position.

The switchgear should comply with AS 62271.200 and be tested for an AFLR classification.

13 Switchgear operation and control

13.1 General

The switchgear shall be arranged for operation by local control or by remote SCADA control. The control equipment, including any motors, shall be rated for continuous operation. The switchgear shall be capable of satisfactory operation with voltage variations as detailed in TS 00011.

13.2 Direct current circuit breaker and disconnector control supply

The protection and control supply for the operation of the DCCB and disconnector shall be obtained from the 125 V dc battery system. All panels of the switchgear shall be individually supplied from the 125 V dc distribution board. See Appendix C for further information.

The 125 V dc control equipment shall be continuously rated for operation on a nominal 125 V dc supply. The control equipment shall be capable of satisfactory operation with the voltage variations specified in TS 00011.

The 125 V dc supply is not a filtered supply and can contain harmonics and spikes. The manufacturer shall ensure their equipment is compatible with the 125 V dc supply and install a filter if required so the supply is suitable for all equipment within the DCCB metal enclosed switchboard.

Two battery systems exist at a traction substation which is a bulk supply point and at critical traction substations. At these locations the switchgear will normally be allocated so that half the DCCBs panels are supplied from battery number one and half are supplied from battery number two.

13.3 Local or remote control

A Local/Remote changeover switch shall be installed on each panel that has a DCCB. Where the DCCB has an associated disconnector, the switch shall be interlocked with both the DCCB and disconnector.

When the changeover switch is in the local position, the SCADA controls are disabled for both the DCCB and disconnector (where installed) and only the local control is enabled. This is applicable for all types of DCCB.

When the changeover switch is in the remote position, the local controls for a line DCCB and associated disconnector are disabled and only SCADA control is enabled.

When the changeover switch is in the remote position, the local controls for a rectifier DCCB are disabled and only control from the respective HV ACCB or SCADA control is enabled.

The method of implementation of the controls shall be suitable for a SIL rated system.

13.4 Direct current circuit breaker controls

The requirements in Sections 13.4 to 13.4.7 are applicable to all types of DCCBs unless otherwise stated.

A DCCB close or open command can originate from either the SCADA system or from the local control located on the DCCB low voltage panel for a line and bus-section DCCB.

The open and close command for a rectifier DCCB can originate from either the HV ACCB, the SCADA system or from the local control located on the DCCB. The SCADA control is via the HV ACCB panel where both the DCCB controls and a Local/Remote changeover switch are located.

The DCCB shall close without delay when the close command signal is applied. While this command signal is applied, the DCCB shall not make a second attempt to close if it fails to close on the first attempt. The operation shall be trip-free.

The DCCB shall open without delay when the open command signal is applied.

Continuously rated control equipment shall be provided to make the successful closing of the DCCB independent of the length of time that the manual control device is held in the 'close' position and to ensure that only one closing attempt can be made if the control device is held in the 'close' position.

13.4.1 Manual operation and degraded mode

A mechanical push button or similar device for tripping the DCCB shall be provided on the DCCB.

In degraded mode when the DCCB cannot be closed (for example, loss of 125 V dc supply, control circuit failure and so on) the DCCB can be closed locally using special tools or other means.

13.4.2 Supervisory control and data acquisition operation

The normal operation of the DCCB is via the SCADA system. See Section 21 for requirements of SCADA control of the DCCB.

13.4.3 Local control and indication

In addition to the position indicator located on the DCCB, a visual indication of the state of the DCCB shall be provided by LED type lights mounted on the front of the DCCB low voltage panel. The colour red shall be used to indicate closed and the colour green to indicate open in accordance with TS 00011.

Local control of the DCCB shall be provided on the DCCB low voltage panel to open and close the DCCB. If colours are used, then the colour green shall indicate the action device to open the DCCB. The colour red shall indicate the action device to close the DCCB.

13.4.4 Direct current circuit breaker mechanical open and close indicator

The DCCB shall be fitted with a mechanically operated indicator, indelibly marked, to show whether the DCCB is open or closed.

The word OPEN shall be visible only if the DCCB is open. The word CLOSED shall be visible only if the DCCB is closed. The words OPEN and CLOSED may be replaced by ‘O’ and ‘I’ respectively.

If colours are used in addition, then the colour green shall indicate the open condition. The colour red shall indicate the closed condition.

13.4.5 Direct current circuit breaker operation counter

A non-resettable, memory-retentive operation counter (nominally mechanical) shall be provided to record the number of openings on the DCCB. However, alternatives to a mechanical counter may be provided if approved by PAM.

13.4.6 Automatic reclose of line direct current circuit breakers

All line DCCBs shall have provision for automatic reclose after a trip that was initiated by a dc protection relay – overcurrent setting, di/dt, delta I.

Line DCCBs shall not automatically reclose for a trip by DAOL, thermal OC, IDMT and undervoltage.

After a set number of unsuccessful recloses the DCCB shall remain open and effectively be in a L/O state. The L/O state disables the ability to close the DCCB and can only be reset by a DCCB open command. The DCCB can only then be closed by a DCCB close command.

The following parameters associated with automatic reclosing shall be adjustable:

- maximum number of consecutive automatic reclose attempts
- time delay between the DCCB trip and the reclose initiation
- minimum period of time from successful DCCB close to subsequent DCCB trip for reset of reclose counter (reclaim time).

Reclosing the DCCB should be subject to a line healthy test. See Section 13.9.2 for further details.

13.4.7 Automatic reclose undervoltage characteristic

The DCCB shall not reclose if the 1500 V dc supply falls below a predetermined voltage. The undervoltage setting shall be selectable in the range from 1000 V dc to 1250 V dc.

13.5 Two position – positive and negative busbar disconnector

The two-position disconnector shall have the following positions:

- Position 1: 1500 V dc positive bus selected (CLOSED position). With the DCCB in the closed position the OHW is connected to the 1500 V dc positive busbar.
- Position 2: negative bus selected (TO RAIL position). With the DCCB in the closed position the OHW is connected to the negative busbar.

The disconnector shall be able to be operated using the motor, remotely or locally, as well as manually.

13.5.1 Manual operation

The motor drive design shall allow manual operation of the disconnector in the event of motor drive failure or loss of the 125 V dc control supply. The manual operation of the disconnector shall be possible with minimal use of tools or equipment.

13.5.2 Supervisory control and data acquisition operation

The normal operation of the disconnector is via the SCADA system. See Section 21 for requirements of SCADA control of the disconnector.

13.5.3 Confirmation of disconnector position

Confirmation of the two disconnector positions shall be provided. Confirmation shall be conveyed electrically via indicators.

Acceptance of confirmation via indications shall be provided with a detailed engineering analysis of the design principles and analysis to support the fail-safe determination and suitable for a SIL rated system.

13.5.4 Local control and indication

The position of the disconnector shall be provided by LED type indications mounted on the front of the corresponding DCCB low voltage panel. The colour red shall be used to indicate the closed to 1500 V dc positive busbar position and the colour blue to indicate the closed to negative busbar position.

Local control of the disconnector shall be provided on the respective DCCB low voltage panel. If colours are used, the colour blue shall indicate the action device to change the disconnector to the closed to negative busbar position. The colour red shall indicate the action device to change the position to the closed to 1500 V dc positive busbar position.

13.6 Direct current circuit breaker and disconnector interlocking

To prevent unsafe operation, the mechanism of the DCCB and the corresponding disconnector shall be interlocked in accordance with EN 50123-6.

The following requirements shall be met, in addition to the requirements of EN 50123-6:

- connection of an OHW feeder to negative busbar shall only be possible if the voltage on the OHW feeder is below a predetermined value
- where the DCCB is required to be in the closed position to affect the connection of the OHW feeder to negative busbar, then all methods of tripping of the DCCB shall be disabled when in this state.

13.7 Padlocking requirements

To prevent unauthorised operation the following shall have the ability to be fitted with padlocks:

- all 1500 V dc shutters shall be able to be locked in the CLOSED position
- the two-position disconnector shall be able to be locked in the TO RAIL position or disabled electrically by the operator
- the DCCB shall be able to be locked in the OPEN or CLOSED position.

The DCCB Local/Remote changeover switch shall be able to be locked in either position.

13.8 Rail connection sensing

A sensing circuit shall be used to determine if the disconnector is electrically connected to the negative return rail. One method is to pass a current via a circuit loop using two connections to the traction return rail.

There shall be an indication on the front of the panel to show confirmation of the disconnector position and connection to rail. SCADA indication shall also be provided.

The rail connection sensing equipment shall have appropriate protection to prevent damage due to the application of system nominal voltage and overvoltage.

13.9 Line overhead wiring testing

Sections 13.9.1 and 13.9.2 describe the line testing requirements which shall be incorporated in the switchgear for each line panel. The tests shall assist in safe operation and provide diagnostic information to the ESOs.

13.9.1 Voltage sensing

The potential difference between the rail connection and the OHW connection shall be continuously monitored. The connection of an OHW feeder to the negative busbar shall only be possible if the potential difference is below a set level.

Where the configuration of the switchgear requires both the DCCB and disconnector to be closed to effect the connection of the OHW feeder to negative busbar, the disconnector can be in the TO RAIL position, but the DCCB cannot be closed unless the potential difference is below the set level.

See Section 15 for further details.

13.9.2 Line healthy test

A method of determining if the OHW is healthy (no connections to rail) shall be provided.

Prior to energising the OHW, a test shall be conducted to determine if the OHW is healthy. This test should be activated by the protection relay on request of a DCCB close command when the disconnector is in the CLOSED position. Other means of activating the test shall be approval by PAM.

The following configurations shall be possible:

- test occurs automatically prior to a DCCB reclose attempt (automatic testing shall be able to be disabled if required)
- if the OHW fails the test then the DCCB shall not close
- the ESO can activate this test independently of closing the DCCB

- the ESO can disable this test if required prior to closing the DCCB
- the test shall be inhibited if the DCCB is in the withdrawn position
- the test shall be inhibited if the disconnector is in the rail position.

The line healthy test equipment shall be implemented to ensure compliance with isolation requirements in PR D 78000.

13.10 Firmware and software

COTS equipment for general application shall be supported by evidence of reliability and maintainability based on AS IEC 60300 or an equivalent standard.

System safety of COTS equipment is managed as part of the safety assurance provided by the TAO for new or altered assets in accordance with TS 04981.

Non-railway specific equipment that provides functional safety shall comply with AS 61508 or the appropriate product specific safety standard.

Individual equipment reliability, availability and maintainability performance shall satisfy the following requirements when installed in the defined environment unless varied by a particular requirement:

- Equipment shall include traceability information to support configuration, maintenance and investigation of hardware issues or software issues or both.
- Clear identification of firmware, software and application data for use by the maintainer shall be provided.
- Control, operation and use of an on-line support tool that can make configuration changes to operational equipment shall be included in the relevant RAMS framework and security framework.

Firmware and software of IEDs used for the control, operation and protection functions shall have their revisions managed in a controlled manner with associated documentation.

The firmware and software shall comply with the following requirements:

- During the development of the switchgear any software and firmware revisions shall be recorded with details of the change.
- The FATs and onsite commissioning documentation shall include the firmware and software version for each IED.
- The final version of the firmware and software shall be documented in the operations and maintenance manual and relevant drawings. The final version of the firmware and software is the version installed in the respective IED that was verified at the FAT.

- The equipment documentation shall detail any action that needs to be carried out prior to operational use of a spare programmable part to ensure that the equipment is suitable for use.

13.11 Off-line support tools

An off-line support tool is used as part of the design, testing and configuration of new operational equipment or systems or alteration of existing operational equipment or systems. An off-line support tool may be used as part of a training facility.

In addition to complying with TS 01515.1 the off-line support tools for application data shall include functionality for the following:

- version management
- data comparison
- application data and configuration backup, restore and archive
- protection from cyber security hazards as specified in Section 13.12.

An off-line support tool shall be available to enable comprehensive testing of the application data and system operation in a factory acceptance test environment. This off-line support tool for testing shall provide a capability for automated repetitive testing activities.

13.12 Cyber security requirements

Cybersecurity shall be implemented for the dc protection relay and DCCB control module including the following equipment and configuration:

- products – hardware, firmware and software
- support tools – online and offline support tools for design, configuration and maintenance
- data – design, configuration, transient and historical.

The equipment and configuration in the preceding bullet list shall comply with cybersecurity requirements for product suppliers specified in TS 04990.

Additional cybersecurity requirements can apply to products following the application of TS 04990 by the asset owner and system integrators.

13.13 Anti-condensation heaters

Anticondensation heaters (230 V ac, 50 Hz) with a control humidistat switch shall be fitted to each panel if required.

Anti-condensation heaters shall be capable of being switched on or off by a manual on/off switch and shall have LED type lights to show the heater is on. The manual switch and the

indication lights should be mounted on the corresponding DCCB low voltage panel of the switchboard.

14 1500 V dc protection requirements

14.1 General

Sections 14.2 to 14.7 detail the protection requirements for detecting faults on the 1500 V dc OHW feeders, 1500 V dc bus-section, 1500 V dc rectifiers and the 1500 V dc switchgear frame.

Refer to TS 03735 for additional information on protection schemes.

The DAOL protection function shall be integral to the DCCB.

The delta I, current rate of rise and intertripping are functions that shall be implemented in a dedicated protection relay. The protection relay shall also have an overcurrent setting function.

A protection relay shall not be used for any control and interlocking functions. Where there is any failure of the relay, the control of the circuit breaker shall not be affected.

14.2 Line direct current circuit breaker

Sections 14.2.1 to 14.2.10 contain protection requirements for line DCCBs. The line DCCB shall trip for current in the forward direction which is defined as current feeding away from the 1500 V dc positive busbar.

14.2.1 Direct acting over load setting

The DCCB shall have an overcurrent setting range of 4 kA (maximum low end of range) to 8 kA (minimum high end of range). The calibration shall be adjustable in a maximum of 500 A steps. All calibration points shall be clearly marked. The setting shall be clearly visible.

The actual current required to trip the DCCB shall not vary by more than ±10% from the setting with any fault up to the specified maximum fault rating.

14.2.2 Primary overcurrent setting

The primary overcurrent setting (implemented in the dc protection relay) shall have a minimum resolution of 1% of In (80 A increments). It shall be able to be set between 0.1 x In (800 A) and minimum of 2 x In (8000 A). The accuracy of the trip setting shall be better than ±5%.

The protection relay shall generate a trip signal before a DAOL operation has opened the DCCB so that fault measurements are always stored in the relay's memory.

The protection relay shall have the ability to store two overcurrent settings (low setting and high setting) which can be selected via a remote signal sent to the protection relay.

14.2.3 Current rate of rise characteristic (di/dt)

The protection relay shall initiate a DCCB trip if the rate of rise exceeds a pre-determined value which is greater than the expected train requirement and detects close-up faults to the busbar.

The tripping of the DCCB for a rate of rise setting is not dependent on the magnitude of the fault current reaching the overcurrent setting.

14.2.4 Delta I

The protection relay shall initiate a DCCB trip if the step current step exceeds a pre-determined value. The pre-determined value shall allow for step change associated with pantographs traversing across OHW sections and due to regeneration from rolling stock.

This setting is independent of the overcurrent settings.

14.2.5 Varying busbar voltage characteristic

The protection relay shall have the capability for programming falling and rising voltage characteristics. This is used by the protection relay to adjust the overcurrent protection setting where the location does not have a rectifier connected to the 1500 V dc positive busbar. This typically includes the following:

- sectioning huts
- traction substations with rectifiers out of service for maintenance
- new traction substations that have staged commissioning and are first commissioned as a sectioning hut.

The protection relay characteristics listed in this section shall not apply for the 1500 V dc metro network.

14.2.6 Undervoltage detection

The voltage on the OHW feeder shall be monitored. When the voltage falls below 1050 V dc the DCCB shall be tripped.

Automatic reclose is not enabled for an undervoltage trip, refer to Section 13.4.6 for details.

Applicable to 1500 V dc metro, an undervoltage protection shall be provided for each track feeder DCCB and yard feeder circuit breaker to detect the remote short circuit condition by the drop in OHW voltage. The undervoltage relay outputs shall be connected to an intertrip and transfer trip scheme intertripping the track feeder DCCB at the adjacent traction substation feeding the same section of track. Indication both local and remote shall be provided for operation of the undervoltage device.

Undervoltage relay shall be equipped with time delay facilities with adjustable time delay of 0 to 5 seconds with setting step of at most 0.5 seconds for the 1500 V dc metro network.

14.2.7 Lockout

The DCCB shall be in a locked out state when the attempted number of automatic recloses exceeds a set value, this is linked with the line test function (see Section 13.4.6 for further details).The DCCB remains in an open state and cannot be operated either locally or remotely until the ICON operator sends a 'Protection L/O' reset command.

14.2.8 Intertripping (heavy rail)

Where a DCCB intertripping scheme is required then on detection of a fault, the protection relay shall send a trip signal to the corresponding DCCB at the other end of the feeder. A provision shall be made to receive an intertrip signal from the DCCB at the other end of the feeder. The intertrip signal is conveyed over a duplicate fibre scheme.

When an intertrip scheme is installed then an intertrip interface panel will also be installed which houses the equipment associated with the scheme. Refer to TS 00272 and TS 00273 for further details on the implementation of intertripping and associated interface panels.

14.2.9 Intertripping (metro)

Each track feeder DCCB shall have an intertrip circuit to the track feeder DCCB which feeds the other end of the same OHW section. The circuit shall automatically trip the track feeder DCCB at the far end of the OHW section when the circuit breakers trips by the protection device:

- direct acting OC series trip device
- undervoltage protection device
- instantaneous OC protection device
- definite time lag OC protection device
- rate of rise OC and delta I protection device
- frame leakage protection device after a time delay.

The dc intertrip changeover switches shall be provided for each dc switchboard so that when that 1500 V dc positive busbar is taken out of service, transfer-tripping of the track feeder DCCB of the adjacent traction substation feeding the same OHW section can be maintained. The OHW bypass isolators associated with the out of service 1500 V dc positive busbar are closed so that the OHW system can still be fed from both ends for that particular OHW section.

The changeover control switch shall be installed inside a wall mounted panel at the room accommodating the dc switchgear or at the front panel of the dc switchgear along with the transfer trip isolation links.

The operation of the intertrip and transfer trip scheme shall be completed with operating two changeover switches on the changeover control panel. One changeover switch shall be provided for Up track. The other changeover switch shall be provided for Down track. Each changeover switch shall have two positions, NORMAL and BYPASSED. The switch shall be able to have a padlock fitted for both positions. The intertrip and transfer trip system shall operate from the 125 V dc battery supply. The intertrip path between two traction substations shall be via optical fibre cables.

14.2.10 Trip simulation

A command to simulate tripping of the DCCB shall be a function of the protection relay. Operation of the trip simulation command shall not inhibit the normal automatic re-close function of the DCCB. The trip simulation command shall enable the operator to test the auto reclose timing and lock out functionality. This is applicable to line DCCBs only.

14.3 Rectifier DCCB (heavy rail)

The rectifier DCCB shall trip for a current (nominally greater than 1000 A) in the reverse direction. The reverse direction is defined as towards the rectifier.

The operation of certain protection devices and equipment interlocks specified in TS 03821 also cause the rectifier DCCB to trip. This trip is normally conveyed from the respective HV switchboard rectifier ACCB panel and can be in the form of multiple voltage free contacts. The exact details depend on the HV switchboard control and protection implementation.

14.4 Rectifier direct current circuit breaker (metro)

Auxiliary contacts shall provide remote indication that the circuit breaker has tripped by reverse current. The setting shall be no more than 50% of the circuit breaker rating. Intertripping between the rectifier DCCB and the rectifier transformer ACCB shall be provided. The rectifier DCCB shall trip when the rectifier transformer ACCB trips or vice versa.

The rectifier DCCB shall only be closed when the rectifier transformer ACCB is closed.

The rectifier DCCB breaker shall only be closed when the negative return disconnection switch is closed. The negative return disconnection switch shall only be open when the rectifier DCCB breaker is open.

Indication both local and remote shall be provided for the operation of the reverse current protection device.

14.5 Bus-section direct current circuit breaker

The bus-section DCCB shall trip when a frame leakage fault is detected. The direction of the fault current can be in either direction. The bus-section DCCB shall not have any other protection installed.

14.6 Switchgear frame fault

The switchgear frame shall be connected to the locations earthing system via a frame fault detection device located in the switchgear, in accordance with section 6.5.7 (method a) of EN 50123-7-1:2003.

Where the DCCB switchboard consists of multiple sections a frame fault detection device for each section shall be present.

When a fault is detected, the following shall occur:

- All DCCBs on the associated section of the switchgear to open including all bus-tie DCCBs connected to the section.
- The rail earth contactor to close (auxiliary contacts required to implement this).
- The 1500 V dc rectifiers connected to the associated switchgear section to lock out by means of the rectifier multi trip relay, manual reset relay. The auxiliary contacts from the frame leakage relay shall implement this.

The rectifier 1500 V dc positive cables are not included in the switchboard frame fault scheme. The screens of these cables are connected to the rectifier power cubicle frame leakage scheme only. At the 1500 V dc switchboard end the cable screens shall be secured to a busbar (mounted on insulators) located inside the cable compartment and left floating. The screens shall be mechanically secured, with the clearances required by EN 50123 maintained.

The bus-section 1500 V dc positive cables are included in the switchboard frame fault scheme. One end of the cable screens of these cables shall be connected to the switchboard frame leakage scheme. The other end shall be secured to a busbar and left floating. The switchboard frame leakage scheme chosen shall ensure minimal operational impact.

14.7 DC traction protection relay

The dc protection relay (located on the line DCCB) shall be a relay designed and manufactured specifically for use in a substation environment with the specific purpose of providing protection functions for direct current traction networks.

The dc traction protection relays shall be type approved in accordance with TS 06178.

14.7.1 Programming of relay

The switchboard manufacturer is responsible for programming and providing assurance for the protection relays installed on the switchboard including meeting requirements of IEC 61511 and satisfying all requirements of TS 04981.

The design TAO shall provide independent assurance including requirements of IEC 61511 and TS 04981.

Dip switch settings, software settings and so on for programmable devices or IEDs shall be fully detailed in the operations and maintenance manual and associated inspection and test plans.

TfNSW will provide the relay configuration details to ensure that the relay input and output assignments and parameters are consistent with relays already installed.

15 1500 V dc voltage measurement

The voltage of the OHW connected to each line panel and the voltage on each positive busbar section shall be continuously measured. An appropriate transducer to provide electrical isolation from the 1500 V dc circuit shall be installed with an output signal for the voltmeter, protection relay on line panels and SCADA analogue measurement.

See Section 20 for requirements of instruments and transducers.

16 1500 V dc measurement

The 1500 V dc current shall be continuously measured for all line and rectifier panels. The method of measurement shall provide a suitable output signal for the ammeter, protection relay on line panels and SCADA analogue measurement.

See Section 20 for requirements of instruments and transducers.

17 1500 V dc feeder testing

The 1500 V dc feeders shall be individually tested after major maintenance and commissioning activities. A means shall be provided to enable the connection of test equipment to the feeder for insulation resistance and continuity tests.

The connection of test equipment to the feeder shall be carried out with the feeder connected to rail and the rail connection is then removed for the duration of the test.

Access to the feeders should be provided without the need to dismantle or remove panels of the switchgear.

18 Cabling, terminations and busbars

18.1 General

Sections 18.1 to 18.8 detail the requirements for 1500 V dc positive cables, 1500 V dc negative cables and main busbars.

The equipment shall be complete with all requisite plug connections for main, auxiliary and earthing contacts, with all busbars, wiring, controls, necessary for operation depending on the detailed design.

18.2 1500 V dc positive busbar

The 1500 V dc positive busbar shall extend through the switchgear and be in its own compartment. See Table 3 for the required rating of the busbar.

18.3 1500 V dc positive cables (heavy rail)

The quantity of 1500 V dc positive cables required to be connected to the switchgear can vary depending on the location and whether the DCCB panel is a line, bus-section or rectifier panel.

Table 10 details the maximum number of 1500 V dc positive cables that is required for connection to the switchgear.

Table 10 – 1500 V dc positive cable requirements

Switchgear panel	Number of cables
Line DCCB	8 × 400 mm²
Bus-section	16 × 400 mm²
Energy or voltage support equipment	4 × 400 mm²
Rectifier DCCB	8 × 400 mm²
Harmonic filter and surge arrester panel	Not applicable

The current type approved lug with the 1500 V dc cables is a long palm, long barrel with 2 × Ø14 mm holes at 50 mm centres. Alternate lugs and associated connection will be considered by PAM with appropriate engineering assurance submitted by the design TAO.

Cable entry shall be at the rear and bottom of the switchgear.

The line DCCB cable compartment requires the quantity of eight cables to allow for locations that have an OHW section that requires a backup DCCB connected in parallel. The paralleling is completed on the line side of the DCCB with cables. These OHW sections (for example, maintenance centres, critical sidings) are typically a single end feed with the normal arrangement being one DCCB is closed and one DCCB is in the open position.

18.4 1500 V dc negative cables (heavy rail)

The 1500 V dc negative control cabling required for the DCCB control and voltage measurement can be connected to the bar used for the rail connection associated with the two-position disconnector.

Individual DCCB panels shall have separate individually fused negative cable connection to the busbar.

18.5 1500 V dc bus-section cables

The quantity of 1500 V dc positive cables installed between bus-section DCCBs shall match the current rating of the 1500 V dc positive busbar. A lower quantity of cables which results in a current rating lower than the 1500 V dc positive busbar may be installed subject to network modelling and approval of PAM.

18.6 1500 V dc rail connection

The rail point of connection for each of the disconnectors shall all be connected together using a solid bar. The end of the bar shall be connected by cables to the substation main negative bar.

The switchgear shall be suitable for the connection of 2 × 240 mm² cables fitted with long palm and long barrel lugs with 2 × Ø14 mm holes at 50 mm centres. The connection shall be at the sides or rear of the switchgear.

18.7 DCCB control cables

The DCCB control cables shall be housed in a flexible trunk of a suitable length for all positions of the DCCB.

The trunk shall be of a suitable material to minimise the risk of damage to the control cables during normal operation of the DCCB. The trunk shall be fitted with a suitable plug at the DCCB end to enable the disconnection and reconnection from the DCCB.

A bracket shall be provided to secure the control cable trunk when not connected to the DCCB.

18.8 1500 V dc positive cable interface

The arrangement of the 1500 V dc positive cable interface where the positive cables enter the cable compartment of the switchboard is critical to ensure the reliability and maintainability of the switchgear for its design life.

Depending on the location of the switchboard and the configuration of the building in which it is located the requirements will vary particularly in regard to environmental conditions such as exposure to water.

The equipment provider and the accredited traction substation designer from the design TAO shall both ensure that the following list of critical design requirements is met:

- suitable for a maximum number of cables and size as specified in Table 10
- suitable for the design life of the switchgear
- minimum or zero maintenance requirements
- suitable for an environment subject to vibration
- prevent the access of vermin
- prevent the access of dust
- depending on the exposure prevent the ingress of water
- provide protection for personnel from electrical faults in the cable compartment where personnel are directly below or in proximity of the switchboard (such as in a basement)
- mechanical support of cables
- accessibility of the 1500 V dc positive feeder cables while the 1500 V dc positive busbar is alive.

19 Low voltage cabinet for secondary equipment

A low voltage cabinet for housing the secondary equipment shall be located on each panel. The low voltage panel shall be a lockable, closed, fully shrouded cabinet of IP3X standard suitable for accommodating protection relays, test blocks, panel meters and other secondary equipment for control and measurement.

Where it is appropriate, equipment may be mounted on a torsion resistant panel door.

The location of the panel shall:

- enable the installation of all secondary wiring and provide accessibility for the termination of wiring
- be suitable for the programming of protection relays and general testing and commissioning activities
- not impede or obstruct the arc venting arrangement associated with the 1500 V dc compartments
- comply with the requirements of AS/NZS 3000 and AS 2067 for access to switchboards.

The low voltage cabinet shall be fitted with a removable gland plate, cable ducting and terminals to maintain the IP rating of the cabinet. The internal cabinet colour shall be a light colour to enable the reading of equipment labels and signage within the cabinet.

The layout within the low voltage cabinet shall comprise the following:

- adequate room for the termination of multi-core control cables, dc auxiliary supply cables and other miscellaneous cables that are required for interfacing with equipment within the substation
- readily accessible cable terminals to enable connection of test equipment associated with protection relay testing and commissioning
- adequate room between duct and cable entry points to allow for the bending radius of cables and to allow for the installation of multi-core control cables
- segregation within the compartment and suitable for the installation of shrouds where required to cover exposed terminals.

Refer to TS 00011 for details on low voltage wiring, terminals and labelling requirements.

20 Instruments and transducers

20.1 General

All instruments, transducers and metering equipment that are required to be fitted shall comply with and Sections 20.1 to 20.4 and TS 00011.

Only flush-mounted industrial type indicating instruments that comply with IEC 60051-1, IEC 60051-2, IEC 60051-3, IEC 60051-7, IEC 60051-8 and IEC 60051-9 shall be used.

Analogue instruments shall have a scale length of at least 90 mm. All instruments on switchgear shall be scaled with the same character type and size. The instruments shall be 96 mm × 96 mm in size, with black scales on a white background.

If a digital meter is provided, it shall have a resolution of at least 100 A and be suitable for displaying constantly varying value of current.

All current operated instruments shall be protected against continuous overcurrent up to 120% of nominal value and high current surges up to the fault rating of the DCCB.

20.2 Transducers

The current and voltage transducers are critical for the correct operation of the dc protection and certain safety functions. Current and voltage transducers shall satisfy the following performance criteria:

- have a linear output
- provide suitable output for implementation of all dc protection functions in Section 13.13 and SCADA remote indications
- be fully compatible with the DCCB control system

- be fully compatible with the dc protection relay (see Section 14.7 for details on the dc protection relay)
- have self-diagnosis ability (watchdog alarm).

The transducers shall comply with Table 11 and parts 2, 3 and table 9 of EN 50123-7:2003.

Table 11 – Transducer general requirements

Parameter	Standard	Rating
Insulation level (current and voltage transducer)	EN 50123-1	3 kV dc
Power frequency withstand voltage (U_{aA})	EN 50123-1	6.9 kV (50 Hz for 1 min)
Output signal (current transducer)	TS 03865 and TS 03866	4 mA to 20 mA or 0 ma to 20 mA
Output signal (voltage transducer)	TS 03865 and TS 03866	4 mA to 20 mA or 0 ma to 20 mA
Frequency response	EN 50123-7	1 kHz (minimum)

20.3 Ammeter

Each DCCB panel shall be fitted with a meter indicating dc current. This ammeter shall be mounted on the front of the panel.

The ammeter for bus-tie and line panels shall be capable of displaying −8 kA to +8 kA with an accuracy of 2.5%. Subject to PAM approval, a line panel installed with a protection relay that displays the current may be used instead of a dedicated ammeter.

The ammeter for rectifier panels shall be capable of displaying −2 kA to +8 kA with an accuracy of 2.5%. If the corresponding rectifier power cubicle has an ammeter installed and the power cubicle is located in the same room as the dc switchgear, the requirement for an ammeter on the rectifier panel shall be subject to consultation with and approval by PAM.

20.4 Voltmeter

Each line panel shall be fitted with a meter indicating the feeder dc voltage. The meter shall be located on the front of the panel. A line panel installed with a protection relay that displays the voltage may be used instead of a dedicated voltmeter subject to approval by PAM.

Where the location is a traction substation, a voltmeter indicating the voltage on the 1500 V dc positive busbar shall be located on the rectifier panel. If the corresponding rectifier power cubicle has a voltmeter installed and the power cubicle is in the same room as the dc switchgear, the requirement for a voltmeter on the rectifier panel shall be subject to consultation with and approval by PAM.

Where a 1500 V dc positive busbar section has multiple rectifiers connected, it is normal operating practice that only one rectifier is in service. In this situation each rectifier panel shall have a voltmeter installed.

If the location is a sectioning hut the busbar voltmeter shall be located on one of the end line panels. The voltmeter shall be clearly labelled '1500 V DC BUSBAR VOLTMETER'.

All voltmeters shall be capable of displaying 0 V dc to 2000 V dc with an accuracy of 2.5%.

21 Supervisory control and data acquisition interface

21.1 General

Sections 21.1 to 21.4 detail the various interfaces to the SCADA RTU.

The SCADA alarms from equipment are implemented by a combination of hard wiring and using the serial link (DNP3 secure authentication or Modbus over RS485) on the electronic protection relays and associated transducers. DNP3 is the preferred communication protocol. Refer to TS 03865 for further details on the serial connection for intelligent electronic devices.

The serial communication port on all electronic protection relays within the switchgear shall be connected together and wired to a terminal strip for connection to the SCADA RTU.

Refer to TS 03865 for details on the SCADA wiring requirements, in particular the requirement for an analogue cable to have the screen connected to the location earth at the RTU end only.

21.2 Hard wired digital inputs

Digital inputs shall be active types where inputs are powered from the switchgear.

For locations where there are two battery systems, digital inputs shall be clearly labelled to identify which battery system is used.

21.3 Hard wired digital outputs

The SCADA RTU provides voltage free contacts which close for a maximum of two seconds for the control functions (for example, close, trip/open) using two wires in the field cabling for each control.

The SCADA RTU voltage free contacts have a maximum current rating of 1 A and a minimum wetting current of 20 mA.

Interposing relays shall be provided for the SCADA initiated close and trip of DCCBs and disconnectors.

21.4 Supervisory control and data acquisition points

Table 12 to Table 15 are typical SCADA points required for each type of panel. The exact point list shall be determined at the detailed design stage. Where the SCADA point can be a serial point the communication protocol should be DNP3.

Table 12 – SCADA points required for line DCCB and disconnector panel

Point name	Point type	Normal state	Hardwired (HW) or serial
DCCB trip	Digital output	NO	HW
DCCB close	Digital output	NO	HW
Disconnector TO RAIL	Digital output	NO	HW
Disconnector to positive	Digital output	NO	HW
Line test activate	Digital output	NO	HW
Protection L/O reset	Digital output	NO	HW
DCCB open	Digital input	NC	HW
DCCB closed	Digital input	NC	HW
Disconnector to positive	Digital input	NC	HW
Disconnector TO RAIL	Digital input	NC	HW
Rail bond applied	Digital input	NC	HW
Rail bond verified	Digital input	NO	HW
DCCB in service position	Digital input	NC	HW
DCCB in isolated position	Digital input	NC	HW
Remote selected	Digital input	NO	HW
Local selected	Digital input	NO	HW
Line test in progress	Digital input	NO	HW
Line test failed	Digital input	NO	HW
Line test passed	Digital input	NO	HW
OHW alive	Digital input	NO	HW
Auto reclose in progress	Digital input	NO	HW
TCS fail alarm	Digital input	NO	HW
dc protection relay watchdog alarm	Digital input	NO	HW
DCCB control module watchdog alarm	Digital input	NO	HW
Transducer watchdog alarm	Digital input	NO	HW
DAOL trip	Digital input	NO	HW
OC stage 1	Digital input	High = fault	Serial

Point name	Point type	Normal state	Hardwired (HW) or serial
OC stage 2 and UV trip (first stage)	Digital input	High = fault	Serial
OC stage 3 and UV trip (second stage)	Digital input	High = fault	Serial
Delta I trip	Digital input	High = fault	Serial
di/dt trip	Digital input	High = fault	Serial
Thermal OC	Digital input	High = fault	Serial
Protection lockout	Digital input	High = fault	Serial
Low trip set	Digital input	High = fault	Serial
Line (feeder) current	Analogue input	Not applicable	HW or Serial
Line (feeder) voltage	Analogue input	Not applicable	HW or Serial

Table 13 – SCADA points required for rectifier DCCB panel

Point name	Point type	Normal state	Hardwired (HW) or serial
DCCB open	Digital input	NC	HW
DCCB closed	Digital input	NC	HW
DCCB in service position	Digital input	NC	HW
DCCB in isolated position	Digital input	NC	HW
Remote selected	Digital input	NO	HW
Local selected	Digital input	NO	HW
Reverse current trip	Digital input	NO	HW
Busbar alive	Digital input	NO	HW
TCS fail alarm	Digital input	NO	HW
DCCB control module watchdog alarm	Digital input	NO	HW
Transducer watchdog alarm	Digital input	NO	HW

Table 14 – SCADA points required for bus-section DCCB panel

Point name	Point type	Normal state	Hardwired (HW) or serial
DCCB open	Digital input	NC	HW
DCCB closed	Digital input	NC	HW
DCCB in service position	Digital input	NC	HW
DCCB in isolated position	Digital input	NC	HW
Remote selected	Digital input	NO	HW

Point name	Point type	Normal state	Hardwired (HW) or serial
Local selected	Digital input	NO	HW
TCS fail alarm	Digital input	NO	HW
DCCB control module watchdog alarm	Digital input	NO	HW

Table 15 – Additional SCADA points for switchboard

Point name	Point type	Normal state	Hardwired (HW) or serial
dc frame leakage (see note)	Digital input	NC	HW
dc frame leakage relay watchdog alarm	Digital input	NC	HW
1500 V dc busbar voltage (see note)	Analogue input	Not applicable	HW or serial

Note: Where a location has multiple busbar sections then there shall be a point for each section.

22 Labelling

In addition to the requirements of EN 50123-2, each DCCB and rail connecting switch panel shall be fitted with a descriptive label on the front and rear. The wording shall be confirmed by the design TAO.

Labelling shall comply with TS 00011.

23 Switchgear tests

23.1 General

The switchgear testing requirements are split into three distinct categories:

- type tests
- FATs
- SATs.

All tests conducted shall be carried out in accordance with a prepared test program which specifies the sequence of tests, the duration of tests and the relevant standard.

The switchboard shall be completely assembled in the factory with all protection devices and auxiliary equipment.

TfNSW reserves the right to witness any of the tests. The manufacturer shall provide TfNSW with six weeks notice of the test commencement date.

All test results shall be included in the operation and maintenance manuals and a copy provided to TfNSW.

At the completion of the testing, the commissioning TAO shall submit a report containing the following to PAM:

- details on the TAO engineering assurance and evidence associated with the manufacturers testing processes and procedures
- photographs of FAT and SAT
- copies of manufacturer's test plans, test procedures, completed test results and reports
- details on any non-compliances that occurred during testing
- a summary of TAO findings and confirmation of compliance with PAM standard or otherwise with appropriate recommendation to PAM.

See Sections 23.1 to 23.4 for further details on the specific requirements and TAO responsibilities.

23.2 Type tests

The type tests as specified in EN 50123 shall be completed with copies of type test certificates, test results and reports submitted as part of the tender documentation.

All type tests shall be completed at an internationally recognised, independent and accredited testing facility.

23.3 Factory acceptance tests

FATs are required to be completed at the manufacturer's premises (unless agreed by PAM). Where a design TAO is witnessing the FAT on behalf of TfNSW they are responsible for witnessing and providing assurance on the tests and requirements.

The design TAO shall ensure that tests and verification activities encompass the full functionality, design and performance requirements of the equipment. At least the following activities and tests shall be included:

- Routine tests as specified in the EN 50123 (all applicable parts).
- Verification of the operation of 125 V dc supplied equipment at the supply limits.
- Verification of specific equipment requirements (wire colours, size, terminal types, segregation and so on) in accordance with TfNSW standards.
- Primary injection for testing of voltage and current transducers and associated metering.
- Demonstration of the replacement of major items of equipment and recording of the time for input into the operation and maintenance manual and to validate the RAMS data.

Verification of the procedures detailed in the operation and maintenance manual and documentation of any special tools identified. The major items include the removal and replacement of the following:

  - two position switch motor
  - two position switch
  - dc protection relay (required to be fully functional and available for service)
  - circuit breaker control module
  - current and voltage transducers

- Inspection of the 1500 V dc cable interface (line and rectifier DCCBs) for suitability of connection of cables, connection of cable screen to insulated earth bar and verify clearance and segregation requirements to relevant EN standards.
- Verification that labelling is in accordance with approved proposed operating diagrams, operation and maintenance manuals, equipment drawings and that they are located in accordance with human factors principles.
- Verification that appropriate signage and labelling is applied in accordance with the relevant Australian standards and EN standards.

23.4 Site acceptance tests

Certain routine tests required by EN 50123 (parts 1, 2, 3, 6, 7-1, 7-2, 7-3) as applicable shall be repeated once the equipment is installed at site.

The commissioning TAO shall in conjunction with the manufacturer determine the routine tests that need to be repeated based on the hazard and risk analysis of transporting the switchgear from the factory to site and the installation activities required.

The following set of tests, as a minimum, shall be conducted:

- dielectric tests in accordance with EN 50123 (parts 1, 2, 3, 6, 7-1, 7-2, 7-3)
- complete operation checks
- SCADA control and alarm tests (including serial communications)
- electrical continuity tests across all 1500 V dc busbar joints
- confirmation of 125 V dc submains allocation from the 125 V dc distribution board to the individual switchboard panel.

24 Human factors

24.1 General

The design of 1500 V dc metal enclosed switchgear shall incorporate the principals of human factor integration in TS 04978.

Human factors aspects to be considered relate to controls and displays, information content, and alarms and alerts.

24.2 Controls and displays

Human factors shall be taken into account in the design of the DCCB and its associated truck.

Human factors shall be assessed in determining how the changing of the DCCB service position is achieved.

The location of the DCCB and rail connecting disconnector local and remote controls, accessibility of the direct current protection relay, ammeter, voltmeter are other key items that the location is critical to ensure suitability for use by the operator and maintainer.

24.3 Information content

The correct labelling of the local and remote controls is critical to reduce the likelihood of operator error while switching.

The design of the labelling and associated diagram that describes the sequence of operation for manual operation and changing of the service position is critical to enable correct operation of the DCCB.

24.4 Alarms and alerts

The local alarms on the switchgear shall be designed to ensure the alarm is clearly visible to the operator and labelled appropriately to ensure clear identification. The identification of the alarms shall be consistent with the operation and maintenance manual and the local instructions onsite.

Audible alarms shall not be used.

25 Environment

The switchgear shall be suitable for locating in traction substations and sectioning huts which are located adjacent to the track. These locations are subject to vibration caused by passing trains. The switchgear shall comply with the requirements in table b.1, annex B of EN 50123-1:2003.

The locations are normally naturally ventilated with ambient temperature ranges as detailed in TS 03744.

The locations contain equipment that is sensitive to EMC emissions. The switchgear shall comply with the requirements of EN 50121-5.

26 Reliability

The reliability of 1500 V dc metal enclosed switchgear is critical to ensure that traction supplies are maintained to the TfNSW metropolitan heavy rail and 1500 V dc metro traction network.

DCCBs and associated disconnectors shall:

- remain in their existing state when any of its control or protection circuits fail
- remain in their existing state when any control voltage is lost
- provide independent fault detection circuits.

In addition to the requirements of Appendix D the manufacturer shall provide evidence that the switchgear being offered is currently used in an environment similar to the TfNSW metropolitan heavy rail and 1500 V dc metro traction network. This evidence shall include the following:

- the switchgear type and ratings
- number of units installed and corresponding duration
- details of the electrical network parameters
- details of the installed environment (for example, proximity to track, type of traction substation, climatic conditions, exposure to dust and so on)
- reliability data that is endorsed by the rail operator where the switchgear is in service.

27 Maintainability

The design of 1500 V dc metal enclosed switchgear shall ensure minimal routine maintenance.

The manufacturer shall provide evidence of the maintenance performed on the switchgear being offered as currently used in a traction network with similar electrical and operational requirements to the TfNSW metropolitan heavy rail and 1500 V dc metro traction network. This evidence shall be from the same network as the reliability data. It shall include:

- technical maintenance plans and associated service schedules
- results of the maintenance activities
- associated maintenance reports and subsequent analysis.

28 Data set associated with equipment

The following shall be supplied by the manufacturer for 1500 V dc metal enclosed switchgear:

- information and drawings, refer to Appendix E for requirements
- technical schedules – the manufacturer shall supply the information in Appendix D
- integrated system support requirements as detailed in Appendix F
- test results.

The data in the preceding bullet list shall remain the property of TfNSW.

See Appendix E for further details on data sets associated with 1500 V dc metal enclosed switchgear.

29 Life cycle costing

Life cycle costing for the switchgear shall be prepared by the design TAO in accordance with TS 01505 and Appendix G of this document.

Appendix A Guide to information requirements for request for tender (informative)

Section A.1 is provided as guidance for preparing a request for tender for 1500 V dc metal enclosed switchgear. These guidelines are not intended to directly form part of any contract.

A.1 Information to be supplied at time of order

Site specific information for the procurement of equipment for a particular location, in addition to the general requirements of this specification should be supplied. Site specific information may include the following:

- approved (for purchase) dc operating diagram for a traction substation. The dc operating diagrams are under configuration control
- whether the location has a single or dual 125 V dc battery system as specified in the approved protection concept for the location
- busbar rating
- any site-specific restrictions on the dimensions or placement of the switchgear
- special transport or unloading requirements
- requirements for specific deliverables including the following:
    - installation and on-site operational testing if required to be carried out by the supplier
    - requirements for training
    - requirement for spares.

Appendix B Switchgear configurations (informative)

The required position of functional units within the switchgear for a specific location will be specified at the time of order in accordance with the approved for purchase 1500 V dc operating diagram.

All configurations require a two-position disconnector to be provided with each line DCCB (L) and energy or voltage support equipment (LV).

The majority of switchgear configurations applicable to the TfNSW metropolitan heavy rail network are detailed in Table 16 and Table 17.

Table 16 – Typical 1500 V dc switchgear configurations for sectioning huts

Configuration (see note 1)	Description
LLLL	2 track location
LLLLLLLL	4 track location

Note 1: Configuration code:

- line (L)
- rectifier (R)
- bus-section (I)
- energy/voltage support equipment (LV)
- harmonic filter panel (H) – no DCCB required.

Table 17 – Typical 1500 V dc switchgear configurations for substations

Configuration (see note 1)	Description
LRLLRLH	2 track with 2 rectifiers and harmonic filter
LRLLRLHLV	2 track with 2 rectifiers, harmonic filter and voltage support
LLRLLLLRLLH	4 track with 2 rectifier and harmonic filter
LLRLLRLLRLLH	4 track with 3 rectifier and harmonic filter
LLRLLIRLLRLLH	4 track with 3 rectifier, bus-section and harmonic filter
LLRLLIRLLRLLH	4 track with 3 rectifier, bus-section and harmonic filter

Note 1: Configuration code:

- line (L)
- rectifier (R)

- bus-section (I)
- energy/voltage support equipment (LV)
- harmonic filter panel (H) – no DCCB required.

Figure 1 to Figure 3 detail three typical configurations used in the TfNSW metropolitan heavy rail traction system. Figure 1 to Figure 3 only show a general diagrammatic representation of the intent of this document and do not detail all the requirements of this document.

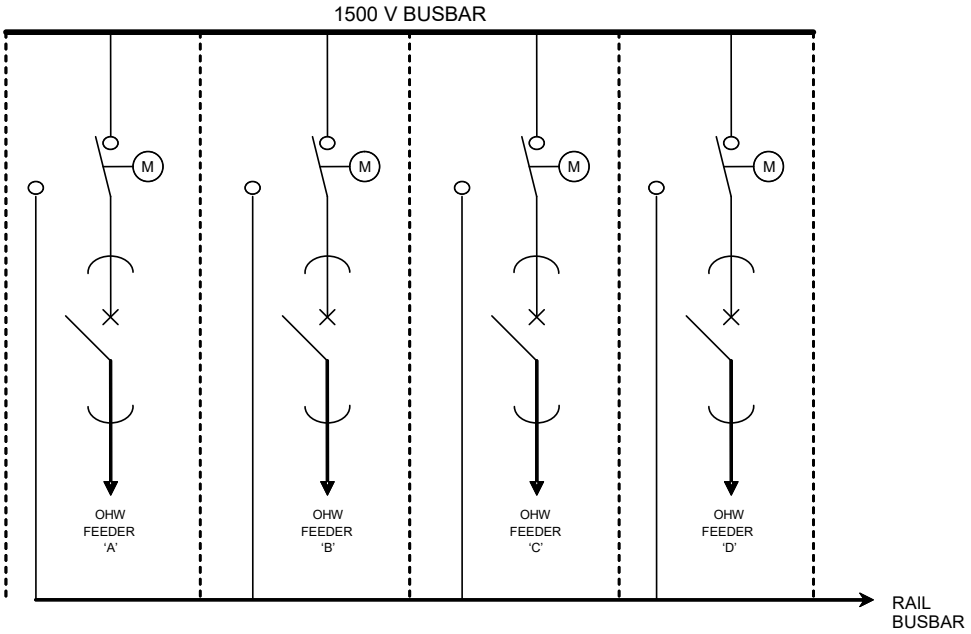

Figure 1 – Sectioning hut configuration (LLLL)

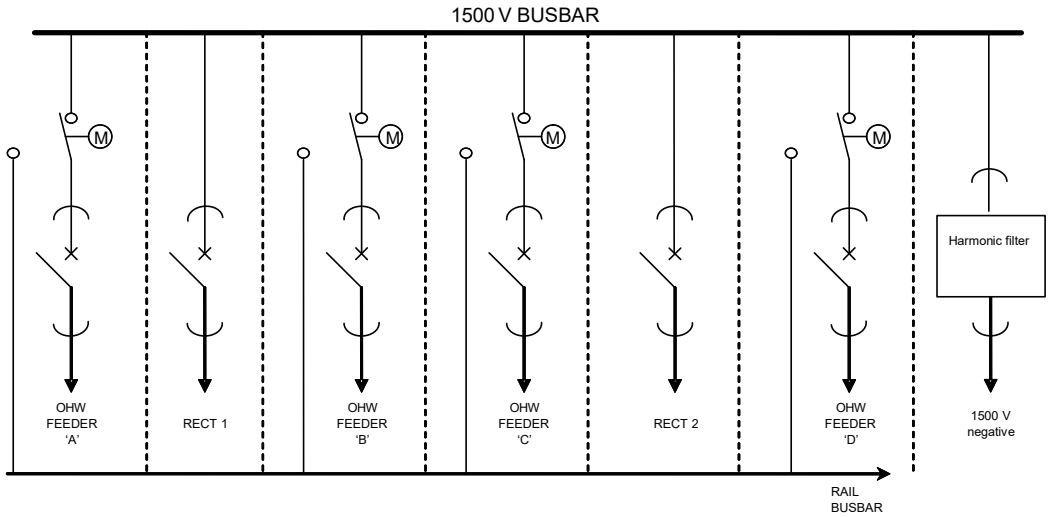

Figure 2 – Substation configuration (LRLLRLH)

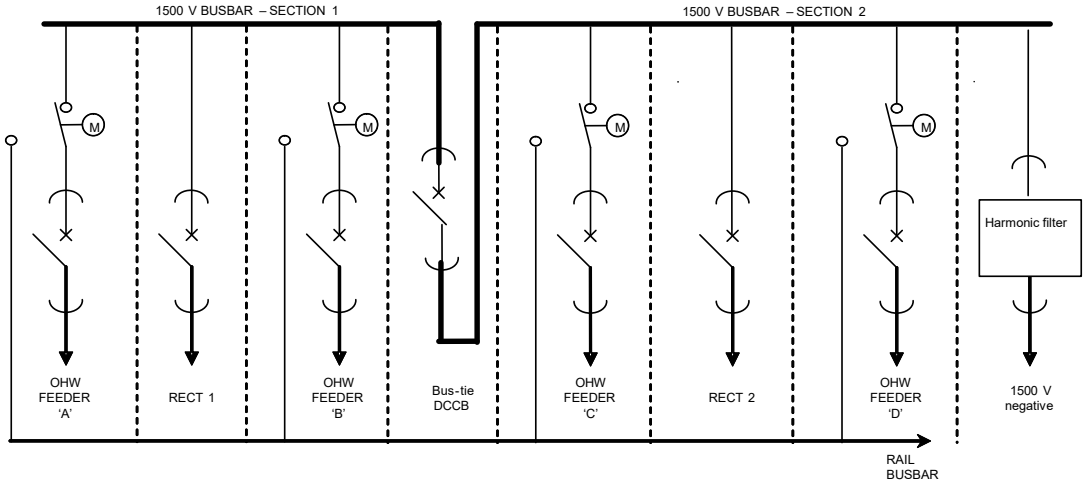

Figure 3 – Substation configuration (LRLILRLH)

Appendix C Typical switchboard auxiliary supply arrangement (normative)

Each panel of the switchboard shall have a dedicated 125 V dc supply from the traction substation or sectioning hut 125 V dc distribution board. Figure 4 illustrates this requirement but with only one set of fuses shown for simplicity. While not shown in the figures all fuses or circuit breakers (double pole) shall be installed in both the positive and corresponding negative supply.

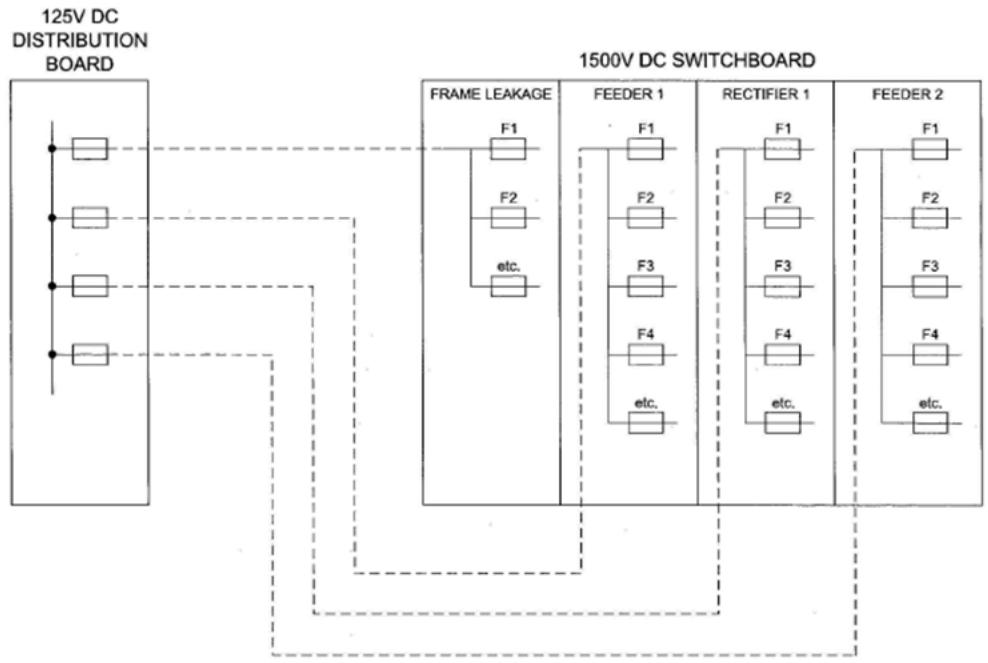

Figure 4 – Dedicated 125 V dc supply from the traction substation/sectioning hut 125 V dc distribution board

Appendix D Technical schedule (normative)

D.1 General

Appendix D contains the technical schedule which shall be competed at the time of tender. The technical schedule details descriptive information that shall be submitted at the time of tender.

D.2 Switchgear technical schedule

The manufacturer shall supply switchgear information listed in technical schedule in Section D.2.

Switchgear details:		
Manufacturer		
Country of manufacturer		
Model		
Switchgear type		
Insulation medium		
IP rating		
Main device type		Withdrawable / non-withdrawable
Design life		Years

Switchgear common ratings:		
Nominal voltage (U_n)		kV
Rated voltage (U_{Ne})		kV
Rated insulation voltage (U_{Nm})		kV
Rated impulse voltage (U_{Ni})		kV
Power frequency withstand voltage (U_a)		kV
Highest system voltage (U_{max})		kV
Lowest system voltage (U_{min})		kV
Rated system current – busbar (I_{Ne})		kA
Rated short circuit current – (I_{Nss})		kA

Switchgear/DCCB physical details:		
DCCB weight (L – line)		kg
DCCB weight (R – rectifier)		kg
Two position disconnector weight		kg

Switchgear/DCCB physical details:		
Weight of line functional unit (including DCCB and disconnector)		kg
Weight of rectifier functional unit (including DCCB)		kg
Weight of bus-section functional unit (including DCCB)		kg
Weight of harmonic filter (including truck)		kg
Weight of harmonic filter or surge arrester functional unit (excluding filter or surge arrester)		kg
Dimensions of line functional unit		L × D × H (m)
Dimensions of bus-section functional unit		L × D × H (m)
Dimensions of rectifier functional unit		L × D × H (m)

Rail connection busbar details:		
Continuous rating		A
Short circuit rating		A
Short circuit duration		s

Switchboard earthing busbar details:		
Continuous rating		A
Short circuit rating		A
Short circuit duration		s

Clearance requirements:		
Distance from rear of switchgear		metres
Distance from side of switchgear		metres
Distance from front of switchgear (including draw out space)		metres
Distance from top of switchgear		metres

Internal arc classification and arc venting:	
Details of arc venting requirements including, options for direction, requirement for external ducting and so on	
Details of internal arc classification	

D.3 Direct current circuit breaker technical schedule

The manufacturer shall supply DCCB information listed in the technical schedule in Section D.3.

Description	Rectifier DCCB (R)	Line DCCB (L)	Bus-section DCCB (I)
Manufacturer			
Model			
Insulation medium			
Breaking characteristic (class designation)			
Current interruption direction			
Test duty cycle			
Principal of operation			
Type of release			
Distance between contacts when in the open position			
Nominal voltage (U_n)			
Rated voltage (U_{Ne})			
Rated insulation voltage (U_{Nm})			
Rated impulse withstand voltage (U_{Ni})			
Power frequency withstand voltage level (U_a)			
Rated service current (I_{Ne})			
Conventional free-air thermal current (I_{th})			
Rated short circuit current (I_{Nss})			
Rated short time withstand current (I_{Ncw})			
Critical current (I_c)			
Temperature rise at I_{Ne} rated service current			
Temperature rise at rated overload conditions			
Track time constant (T_{NC})			
Maximum arc voltage ($\hat{U}arc$)			
Type of arc extinction			

Description	Rectifier DCCB (R)	Line DCCB (L)	Bus-section DCCB (I)
Number and rating of auxiliary contacts			
Direct acting overload setting range			
Closing time			
Opening time as a function of di/dt			
Cut-off current as a function of di/dt			
Resistance of main circuit			
Minimum distance between 1500 V dc circuit and frame			
Noise emission level (during breaking of I_{Ne})			
Maximum number of 400 mm² cables that can be installed			

D.4 Two position disconnector technical schedule

The manufacturer shall supply the two-position disconnector information listed in the technical schedule in Section D.4.

Disconnector:		
Manufacturer		
Model		
Nominal voltage (U_n)		kV
Rated voltage (U_{Ne})		kV
Rated insulation voltage (U_{Nm})		kV
Rated impulse withstand voltage (U_{Ni})		kV
Power Frequency voltage withstand level (U_a)		kV
Conventional free-air thermal current (I_{th})		kA
Rated service current (I_{Ne}		kA
Rated short circuit current (I_{Nss})		kA

Disconnector:		
Rated short time withstand current (I_{Ncw})		kA
Complies with TS 03873		Yes / No
Method of operation		(manual, motor or both)
Supply requirements for motor operation		Voltage and current.
Time to change state (motor operation)		s
Method of confirming disconnector position		
Maximum number of 400 mm² cables that can be installed		
Provide detail on interlocking between DCCB and switchgear		
Provide detail on interlocking between DCCB and disconnector		
Provide details on disconnector interlocking and voltage sensing of OHW		
Are shutters on switchgear able to be fitted with padlock?		

DC protection relay		
1500 V dc protection – protection relay details (include relay technical literature in submission)		
Relay manufacturer		
Relay model number		
Is relay type approved by TfNSW		

Low voltage compartment:		
Size of LV compartment		L × D × H (cm)
IP rating		
Internal colour		
Lockable door?		

Details of cable entry into LV compartment:		
External cables (dc aux supply, SCADA, and so on)		
Internal cables from DCCB compartment and so on		

D.5 Harmonic filter panel technical schedule

The manufacturer shall supply harmonic filter panel information listed in the technical schedule in Section D.5 if specified.

Harmonic filter panel details:		
Filter frequencies.		Hz
Detail of rectifiers (size and quantity) and associated load allowed for in the filter design.		
Reduction in harmonics after filtering		
Fuse size (600 Hz)		A
Fuse size (1200 Hz)		A
Main filter fuse size		A
Time to discharge capacitors		s
Method of interlocking discharge switch with racking out of harmonic filter.		

D.6 1500 V dc busbar surge arrester details

The manufacturer shall supply 1500 V dc busbar surge arrester information listed in the technical schedule in Section D.6 if specified.

1500 V dc busbar surge arrester details:		
Manufacturer		
Country of manufacture		
Model number		
Continuous operating voltage (Uc)		V dc
Nominal discharge current (In)		A (8/20 µs)
Arrester class DC-B		
Short circuit rating (Is)		kA for s
Is this arrester TfNSW type approved		

D.7 Instrument technical schedule

The manufacturer shall supply instrumentation information listed in the technical schedule in Section D.7.

Instrumentation – 1500 V dc current measurement		
Method of measuring current		
Hall effect / shunt manufacturer and model		
Continuous current rating		A
Overload rating		
Accuracy		
Manufacturer of transducer		
Model of transducer		
Auxiliary supply required?		If yes, include requirements
Isolation rating		
Ammeter details		

Instrumentation – 1500 V dc voltage measurement		
Method of measuring the voltage		
Manufacturer of transducer and model		
Model of transducer		
Isolation rating		
Auxiliary supply required?		If yes, include requirements
Voltmeter details		

D.8 Reliability data and supply history

The manufacturer shall supply the following reliability data for each switchboard, DCCB and two-position disconnector:

- failure modes for early, normal life and wear out periods
- mean operating hours between failure modes
- mean time to repair.

The manufacturer shall provide details of any special requirements, test and support equipment including but not limited to the following:

- period (in years) the model or type has been available for purchase
- estimated period before replacement with new model
- number of units in service worldwide
- information in accordance with Section 26.

D.9 Additional descriptive switchgear detail and information

The following general descriptive detail on the switchgear shall be provided with the tender:

- general switchgear overview detailing the construction of switchboard, operation, control and measuring equipment, method of accessing cables for testing, detail on 1500 V cable termination
- details of standards that switchgear complies with
- copies of all type test certificates and reports
- any departures from the requirements of this document.

If there are departures from requirements specified in this standard, details shall be included on a separate sheet.

The following descriptive detail on the DCCB operation shall be provided with the tender:

- details of standards that DCCBs complies with
- copies of all type test certificates and reports
- detailed description of circuit breaker operation, including different DCCB positions
- electrical ratings of relays, coils and related auxiliary equipment for operation
- method of varying the DAOL setting
- detail on proposed method of rail sensing
- arc chute construction and design principle
- details of materials used including insulation, main and arcing contacts, arc chute
- DCCB and switchgear interlocking details
- describe the effect, if any, of temperature variation on current calibration
- detail on maintenance requirements including frequency, type of maintenance, consumables used, estimated duration and requirement for special tools and personnel.

The following descriptive detail on the two-position disconnector operation shall be provided with the tender:

- copies of all type test certificates and reports
- details on standards that two-position disconnector complies with
- description of disconnector construction, including details on motor operation and control, manual operation, disconnector position indication mechanism
- detail on maintenance requirements including frequency, type of maintenance, consumables used, estimated duration and requirement for special tools and personnel.

Appendix E Data set associated with the equipment (normative)

E.1 General

The data sets detailed in Sections E.2 to E.4 shall be supplied by the manufacturer and maintained for the switchgear. This data shall remain the property of TfNSW.

E.2 Information

The base set of required drawings listed in the following shall be provided:

- EN 50123-2 annex A
- EN 50123-3 annex A
- EN 50123-6 annex A.

All drawings shall comply with TS 01547.1.

Additional information and requirements as a deliverable under equipment supply is stated in TS 03742.

E.3 Technical schedule

The information listed in the technical schedule in Appendix C supplied by the manufacturer, shall be maintained for each switchboard.

E.4 Life cycle costing

All the data and assumptions pertaining to the determination of the whole-of-life cost calculations of the switchgear shall be recorded. Refer to TS 01505 for more information. Life cycle costing is prepared by the design TAO as detailed in Appendix G.

Appendix F Integrated system support requirements (normative)

The switchgear manufacturer shall establish and provide the information required to operate and maintain the equipment throughout its operational life, in a cost-effective manner and to a level that is consistent with the planned operational performance and usage of the switchgear. This shall include, but is not limited to, the following:

- specifying maintenance requirements
- spares support including the timeframe for the availability of spares, where they are held, how long the manufacturer will guarantee supply, and any maintenance action required prior to operational use of a spare part shall be fully detailed in the equipment documentation)
- operations and maintenance manuals
- training
- support equipment and tooling.

The integrated support requirements are a significant deliverable in the procurement of new switchgear. Manuals, training, documentation and other support deliverables shall comply with TS 03742.

Appendix G Whole-of-life cost (normative)

Appendix G is provided for use by the design TAO in assessing the whole-of-life cost of the switchgear.

The selection of the most suitable switchgear design shall be made based on minimising the whole-of-life cost. The following factors shall be assessed when determining whole-of-life cost:

- cost of changes to the technical maintenance plan and service schedules or the creation of new manuals and schedules
- cost of decommissioning and disposal
- cost of installation
- cost of inventory spares
- cost of maintenance
- cost of modifications to other parts of the installation
- cost of replacement parts
- cost of special tools
- cost of staff training
- discount rate (example, for multiple units)
- environmental costs
- initial purchase price
- lifetime of equipment
- reliability and cost of consequential damage after failure
- cost of optional tests.

If the switchgear has not previously been type approved by TfNSW in accordance with TS 06178 the costs for the type approval process shall be included in the whole-of-life cost.