TS 03822:1.0

T HR EL 03002 SP

Specification

1500 V dc Rectifier Power Cubicle and Negative Isolator

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Document information

Owner: Director Energy Network and Systems
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Mode: Heavy rail

Discipline: Electrical

Document history

Revision	Effective date	Summary of changes
1.0	14/09/2018	First issue as T HR EL 03002 SP *1500 V dc Rectifier Power Cubicle and Negative Isolator.*
1.0	08/07/2025	Renumbered as TS 03822:1.0. Version number recommenced in line with the new designation. Changes from previous version include the following: • updated references to Transport, Australian and International standards • included the requirement for a filter installed on the 125 V dc supply • added in appendix outlining information to be provided with the RFT.

Preface

This specification is the first issue as TS 03822:1.0 and supersedes T HR EL 03002 SP *1500 V dc Rectifier Power Cubicle and Negative Isolator,* version 1.0.

This document provides the requirements for 1500 V dc rectifier power cubicle and negative isolators for use on the TfNSW heavy rail passenger network within the metropolitan rail area.

The changes from the previous content include the following:

- updated references to Transport, Australian and International standards
- included the requirement for a filter installed on the 125 V dc supply
- added in appendix outlining information to be provided with the RFT.

Table of contents

1 Scope

This specification provides requirements for indoor 1500 V dc rectifier power cubicles and 1500 V dc negative isolators that are type and routine tested and fitted with all auxiliary equipment for use in the TfNSW heavy rail passenger network within the metropolitan rail area.

2 Application

The requirements of this document apply to procurement of new 12 pulse semiconductor 1500 V dc rectifier power cubicles and 1500 V dc negative isolators for use in the TfNSW heavy rail passenger network within the metropolitan rail area.

The requirements of this document do not apply to the operation or maintenance of existing rectifiers or negative isolators in the TfNSW heavy rail passenger network within the metropolitan rail area.

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

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

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

Australian standards

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

AS 2700 *Colour standards for general purposes*

AS 60146.1.1 *Semiconductor converters – Part 1.1: General requirements and line commutated converters – Specifications of basic requirements*

AS 60146.1.1-2002 *Semiconductor converters – Part 1.1: General requirements and line commutated converters – Specifications of basic requirements*

SA TR IEC 60146.1.2 *Semiconductor converters – Part 1.2: General requirements and line commutated converters – Application guide*

SA TR IEC 60146.1.2:2024 *Semiconductor converters – Part 1.2: General requirements and line commutated converters – Application guide*

AS 60146.1.3 *Semiconductor converters – Part 1.3: General requirements and line commutated converters – Transformers and reactors*

AS 60146.1.3-2002 *Semiconductor converters – Part 1.3: General requirements and line commutated converters – Transformers and reactors*

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

Transport for NSW standards

TS 00011 *Common Requirements for Electrical Power Equipment*

TS 01505 (T MU AM 1001 ST) *Life Cycle Costing*

TS 01517 (T MU AM 01002 MA) *Maintenance Requirements Analysis Manual*

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

TS 03741 (T HR EL 00006 ST) *Electrical Power System Signage*

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 03749 (T HR EL 20002 ST) *1500 V DC Cables and Cable Ratings*

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

TS 03865 *Electrical SCADA Interface Requirements*

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

Transport for NSW drawings

EL 0214515 *General, Substations – Rectifier Power Cubicle, 12 Pulse Series Bridge – Arrangement* (This drawing is available from the ECM Planroom. Access to the Planroom is restricted to TfNSW employees and approved external organisations. To obtain access, email planroom@transport.nsw.gov.au)

4 Terms, definitions and abbreviations

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

ac alternating current

ACCB alternating current circuit breaker

dc direct current

DCCB direct current circuit breaker

HV high voltage

LV low voltage

PAM Prioritisation and Asset Management

SCADA supervisory control and data acquisition

TAO Technically Assured Organisation

RFT request for tender

RMS root mean square

TfNSW Transport for NSW

5 TfNSW type approval

All 1500 V dc rectifier power cubicles and associated negative isolators procured in accordance with this specification shall be type approved by TfNSW prior to being connected to the network.

The type approval process is specified in TS 06178.

6 Functional characteristics

Rectifier power cubicles shall provide for the following:

- conversion of 600 V ac from the delta and star windings of the rectifier transformer to a nominal 1500 V dc
- 1500 V dc negative isolator with associated monitoring of position
- frame leakage scheme
- measurement of the rectifier air temperature
- measurement of the rectifier1500 V dc output voltage and current
- connection of cables to the delta and star windings of the rectifier transformer
- connection of 1500 V dc cables or busbar to the rectifier positive 1500 V DCCB
- connection of 1500 V dc cables or busbar to the 1500 V dc negative reactor
- connection of SCADA system auxiliary cabling
- provision for operation in an environment with conditions as prescribed in this specification.

7 General overview of power connection and control

The positive side of the rectifier is connected to the 1500 V dc positive busbar via a 1500 V dc high speed rectifier circuit breaker. The 1500 V dc positive busbar is connected to the overhead conductors of the traction system via 1500 V dc high speed feeder circuit breakers.

The negative side of the rectifier is connected to the traction rails via a 1500 V dc negative isolator and reactor. The rails are unearthed but normally close to earth potential.

The substation ac auxiliary supply (240 V/415 V) is derived from the secondary side of the rectifier transformer with the 600 V ac sourced via fuses located in the rectifier power cubicle. See Section 9.6 for further details.

SCADA equipment is used to provide remote open and close signals for the control of the HV ACCB and 1500 V DCCB associated with the rectifier. The SCADA equipment also provides remote indication of whether the circuit breakers are open or closed and alarm conditions related to the rectifier.

There is a surge arrestor installed on 1500V bus bar and the characteristics of the surge arresters used on the 1500 V dc system are detailed in TS 03872.

Figure 1 provides typical standard transformer and rectifier ac arrangement details.

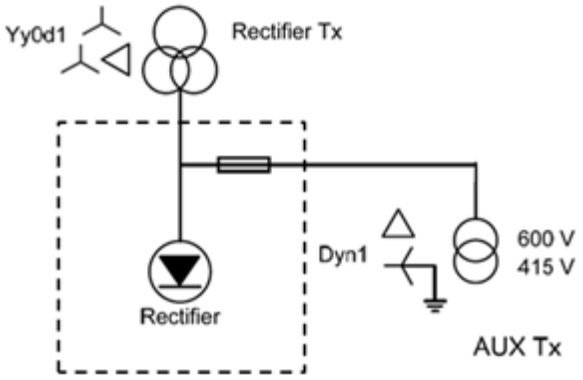

Figure 1 – Standard transformer and rectifier ac arrangement

Figure 2 provides detail on the typical dc substation equipment arrangement.

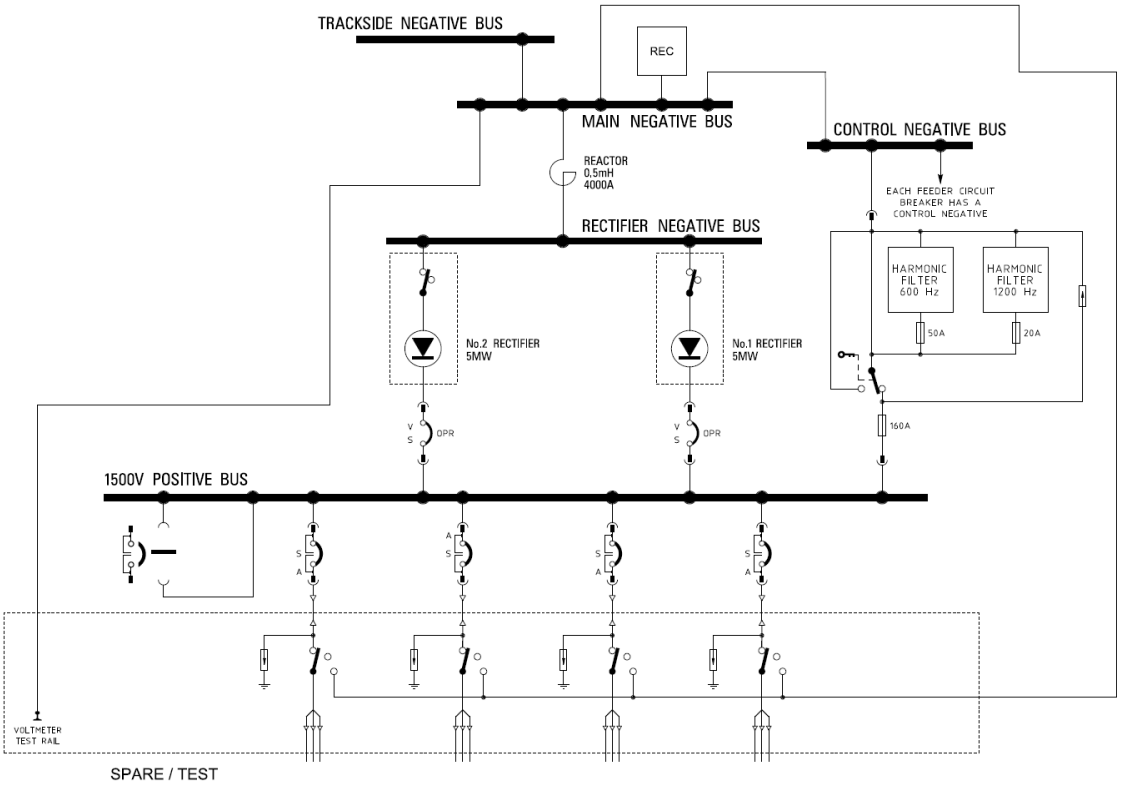

Figure 2 – Typical substation dc arrangement

Figure 3 shows a typical rectifier block diagram indicating the interfaces between the rectifier and other substation equipment.

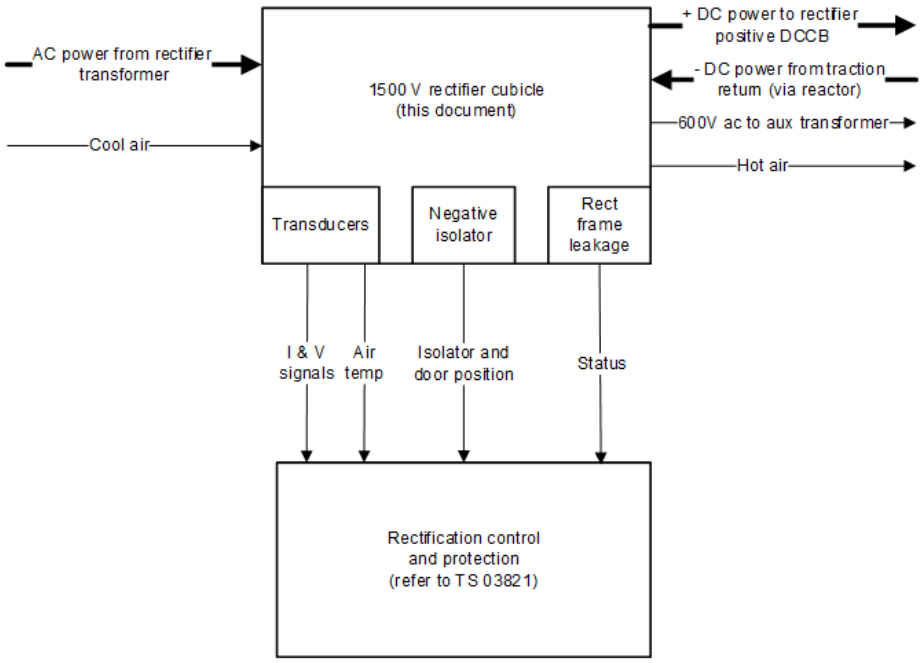

Figure 3 – Rectifier interface block diagram

Note: Figure 3 is for a rectifier incorporating the negative isolator. It does not cover existing locations where the negative isolator is not incorporated into the rectifier power cubicle.

8 Performance characteristics

Table 1 provides details of the general requirements of the rectifier power cubicle.

Table 1 – General requirements of the rectifier power cubicle

Parameters	Designation
General	Indoor
Insulation medium	Air insulated
Cooling method	AN
IP rating	IP2X (see Section 9.10.2)
Category of semiconductor	Non controllable (diode)
Connection number (in accordance with AS 60146.1.3)	12 (The connection number is 12 except the delta winding shall be closest to the negative and the star winding closest to the positive.)
System earthing	Not earthed

Table 2 provides technical ratings of the rectifier power cubicle.

Table 2 – Technical ratings of the rectifier power cubicle

Parameters	Rating
Input	Star winding: 600 V ac delta winding 600 V ac
Nominal full load output voltage	1550 V dc
Maximum external applied voltage	2200 V dc (this is the maximum external applied voltage which the rectifier shall withstand due to the regeneration of trains)
Rated power and associated current rating at full load voltage of 1550 V dc	2.5 MW and 1600 A (not to be used for new locations) 4 MW and 2600 A (not to be used for new locations) 5 MW and 3200 A
Duty class and overload ratings	Duty class VI in accordance with AS 60146.1.1 with special overload conditions in accordance with TS 03873
Minimum clearance between uninsulated 1500 V dc conductors	100 mm

Parameters	Rating
Minimum clearance between uninsulated 1500 V dc conductors and earthed metalwork	80 mm
Ambient temperature range	In accordance with TS 03744

Table 3 provides general ratings of the negative isolator.

Table 3 – General ratings of the negative isolator

Parameter	Designation
Type of disconnector	Two position – closed or open
Number of poles	Single pole
Number of positions	2 positions (closed and open)
Provision of enclosure	Integral to the rectifier cubicle
Class	Category 1 (close and open at no-load)
Electrically operated or manual operation	Manual
Ambient temperature range	In accordance with TS 03744

The negative isolator electrical ratings are aligned with the requirements of EN 50123-1 and are specified in Table 4.

Table 4 – Negative isolator ratings

Parameter	Standard	Rating
Nominal voltage (U_n)	EN 50163	1500 V dc
Rated voltage (U_{Ne})	EN 50123-1:2003 (table 1)	1800 V dc
Rated insulation voltage (U_{Nm})	EN 50123-1:2003 (table 1)	3000 V dc
Rated impulse voltage to earth ($U_{Ni}A$)	EN 50123-1:2003 (table 1)	15 kV peak (1.2/50µs)
Rated impulse voltage across isolating distance ($U_{Ni}B$)	EN 50123-1:2003 (table 1)	18 kV peak (1.2/50µs)
Power frequency withstand voltage to earth (U_aA)	EN 50123-1:2003 (table 1)	6.9 kV (50 Hz for 1 minute)
Power frequency withstand voltage across the isolating distance (U_aB)	EN 50123-1:2003 (table 1)	8.3 kV (50 Hz for 1 minute)
Rated service current – (I_{Ne})	EN 50123-1	≥ 4,000 A (see note)
Rated short time withstand current (I_{Ncw})	EN 50123-1	≥ 30 kA for 250 ms
Rated short-circuit current (I_{Nss})	EN 50123-1 TS 03873	75 kA

Parameter	Standard	Rating
Electrical clearance for 1500 V dc to earth	EN 50123-1:2003 (table 1)	≥ 27 mm
Electrical clearance across the isolating distance	EN 50123-1:2003 (table 1)	≥ 32 mm
Electrical clearance - creepage distance	EN 50123-1:2003 (table D2 material group 1)	≥ 75 mm

Note: The overload conditions as detailed in TS 03873 apply to the negative isolator rating in addition to the continuous rating.

9 Technical characteristics

9.1 General

All equipment supplied shall withstand normal handling during transportation and installation, continuous operation under the conditions specified in this specification. Equipment shall be suitable for the required duty.

All equipment shall be easily accessible with the rectifier power cubicle installed on a flat surface. The rectifier power cubicle shall be transported complete and be simple to install to minimise construction time.

9.2 Environment

Some installations may be located in close proximity to railway tracks that are subject to significant vibration, dust and dirt ingress. The rectifier shall not be adversely affected when operating under these environments.

9.3 Diode assembly

The rectifier shall consist of assemblies of semi-conductor diodes arranged in a series bridge connection for 12 pulse operation.

The design shall incorporate a minimum number of diodes with no more than a total of 24 power diodes. It shall be similar to connection number 12 shown in Table 2 of AS 60146.1.3-2002, except the delta winding. The delta winding shall be closest to the negative and the star winding closest to the positive. The system is not earthed.

The assembly shall be constructed to allow easy access for cleaning insulated sections of the diode assembly.

Sections of the assembly shall be clearly labelled as positive, negative or ac to aid identification during fault finding of diodes. This may be done with the aid of colour coding: red, white and dark blue for ac; brown for positive, light blue for negative; no colour for the series bridge.

9.3.1 Diode protection

Diode protection fuses and diode failure detection equipment shall not be used.

Each rectifier shall be supplied complete with all the equipment necessary for suppression of the hole storage effects, surge voltage suppression and cooling. The surge voltage suppression circuit shall be designed to coordinate with the 1500 V dc busbar surge arrestor.

The diodes shall safely carry the prospective fault currents without rupturing the diode case.

9.4 Conductors

9.4.1 Exposed conductors

Safety clearances to exposed live 600 V ac conductors shall be in accordance with AS 2067 for voltages up to 3.3 kV.

The required taut string line distance is shown in EL 0214515.

9.4.2 Clearances

The minimum clearance in air between uninsulated 1500 V dc conductors and uninsulated 1500 V dc conductors and earthed metalwork are detailed in Table 2.

If the design requires a clearance less than these values then a documented engineering assessment shall be carried out to verify that the design has addressed the following issues:

- accessibility for maintenance and inspections
- use of standard components
- flexing of panels and doors
- the open nature of the rectifier that allows the ingress of vermin, dust and other pollution contaminants.

9.4.3 Connections

The standard connection method is by cable and Table 5 provides details to ensure compatibility with the TfNSW approved cable configurations. Where the proposed method of connection is by busbar (as advised in the RFT) PAM shall be consulted.

The approved cables to interface with the rectifier are detailed in TS 03749.

Cable entry shall be arranged for top entry of the six phases of the main 600 V ac connections. The 1500 V dc positive and negative connections can be either bottom entry or top entry and will be specified in the RFT (see Appendix D). The preference is for the 1500 V dc positive and negative connections to be bottom entry.

The 600 V ac and 1500 V dc terminals shall be fitted with appropriate connecting palms to attach 100 mm lugs as detailed in EL 0214515. The cables used may be either 240 mm² or 400 mm² and appropriate spacing shall be maintained for either circumstance. The maximum numbers of cables are detailed in Table 5.

Table 5 – Quantity of cables

Rectifier continuous rating	AC cables or phase (unscreened)	Positive cables (screened)	Negative cables (unscreened)
2.5 MW	5 x 240 mm^2 or 4 x 400 mm^2	5 x 240 mm^2 or 4 x 400 mm^2	5 x 240 mm^2 or 4 x 400 mm^2
4.0 MW	9 x 240 mm^2 or 6 x 400 mm^2	8 x 240 mm^2 or 6 x 400 mm^2	8 x 240 mm^2 or 6 x 400 mm^2
5.0 MW	12 x 240 mm^2 or 8 x 400 mm^2	10 x 240 mm^2 or 7 x 400 mm^2	10 x 240 mm^2 or 7 x 400 mm^2

Refer to EL 0214515, for palm details. The final size of the 1500 V dc palms is dependent on the number of positive and negative cables required. The configuration of the cable connections to the 1500 V dc busbars is dependent on the overall design but allowances shall be made for maintenance access to the connections and to ensure the cables do not adversely obstruct the flow of cooling air through the rectifier.

The physical arrangement of the connections between the rectifier transformer and the rectifier power cubicle shall be aligned to avoid crossing of the 600 V ac cables. The relationship of the connections is highlighted in Figure 4 which also draws attention to the auxiliary transformer connections. No other major equipment or components are shown.

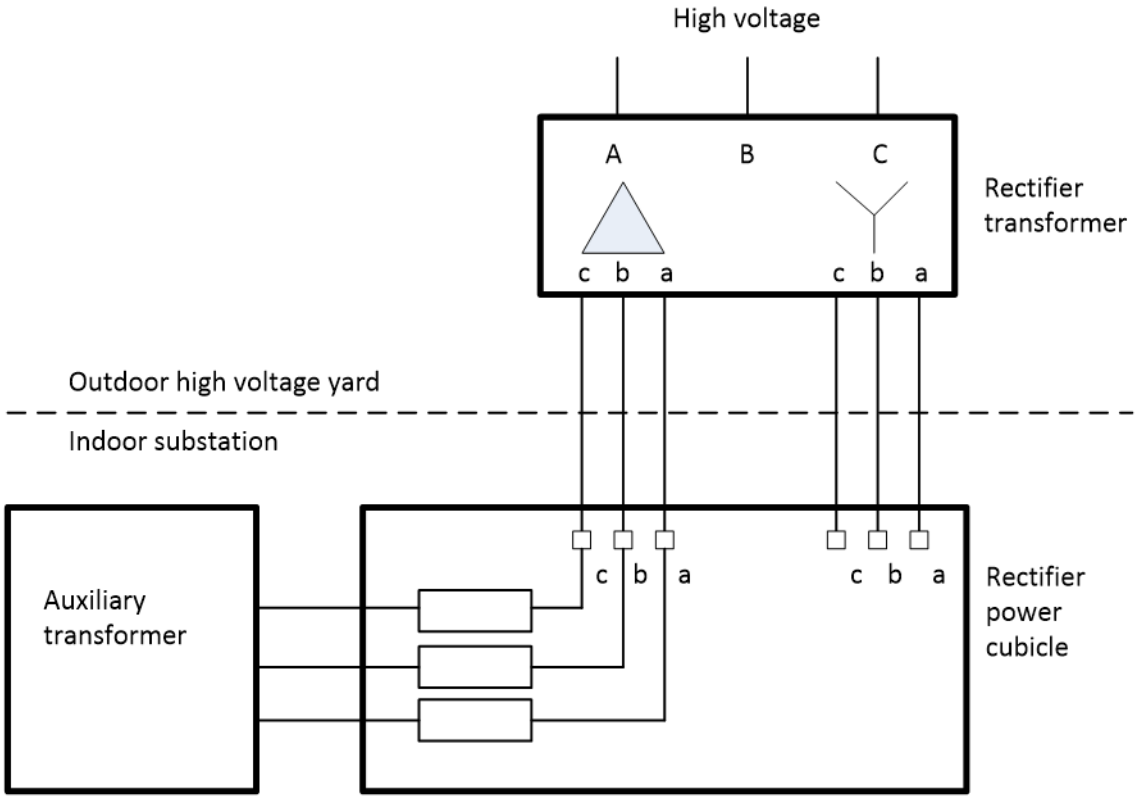

Figure 4 – Rectifier ac connections diagram

9.5 Rectifier frame fault

The rectifier frame shall be connected to the substation earthing system via a frame fault detection device located in the marshalling cubicle of the rectifier.

The frame fault detection device shall operate at a threshold (adjustable) over 1 A dc and not exceeding 100 A dc to detect leakage current between the insulated frame of the rectifier and earth.

The auxiliary contacts shall have a minimum make and break rating of 1 A 125 V dc and 5 A 240 V ac. The nominally open contacts of this device shall withstand a voltage of 5 kV RMS to the main 1500 V dc circuit for 1 minute. The device shall be capable of handling the prospective fault current as determined as part of the rectifier power cubicle design.

The TfNSW heavy rail passenger network within the metropolitan rail area uses a standard protection system consisting of a DCCB (see Section 11.6 for more details) and an ACCB (see Section 11.5 for more details) with backup protection relays.

Requirements for the connection of the device to the substation earth are in Section 9.10.3.

9.6 Auxiliary transformer connections

The rectifier shall provide three fuses (2 kV dc rating) and the facility for termination of three 16 mm² or 25 mm² unscreened 3.8 kV/6.6 kV single core cables for this purpose. The current rating of the fuse depends on the auxiliary transformer size and will be stated in the RFT (see Appendix D).

Suitable cable entry and cable fixing arrangements for top or bottom entry shall be provided and will be specified in the RFT (see Appendix D), with the preference to be bottom entry. The fuses shall be located and mounted to facilitate easy removal and replacement. The fuses and connections shall be clearly and indelibly labelled. See Section 11.4 for further details of auxiliary transformer.

The approved cables to be used to connect the rectifier input to the auxiliary transformer are specified in TS 03749.

9.7 Cooling

The rectifier shall be naturally air cooled. Fan cooling shall not be used.

9.8 Electrical and temperature monitoring

9.8.1 General

To enable TfNSW to extract full capability from its assets real time electrical and temperature parameters shall be measured. These parameters are used for network monitoring and in a theoretical model for simulation of future loading.

See Section 9.8.2 for specific requirements of instrumentation and Section 9.8.3 for thermal model details.

9.8.2 Instrumentation

The rectifier power cubicle shall incorporate transducers to transmit the following information to the rectifier controls to interface with the SCADA system and meters (1500 V dc voltage and current) located in the rectifier marshalling panel and HV ACCB panel:

- rectifier output current (linear output, range 0 to full overload rating in accordance with TS 03873)
- rectifier output voltage (linear output, range 0 to 2200 V dc)
- cubicle bottom (entry), air temperature (linear output, range 0 to 100ºC)
- cubicle top (exit) air temperature (linear output, range 0 to 100ºC)
- heat sink temperature (fibre optic sensor located at hot spot).

The output to the rectifier controls for the SCADA interface shall meet the requirements of TS 03865. The rectifier instrumentation and controls shall be isolated from the 1500 V dc that is contained in the rectifier power cubicle. The isolation requirement is 5 kV RMS for 1 minute and clearances are specified in Table 2.

The preferred method for measuring the current and voltage is by the use of a hall effect dc current transducer and dc voltage transducer. The placement and associated design of these devices shall take into account the following:

- easy access for replacement
- the effects of temperature rise in the cubicle on the instrumentation devices (effect on accuracy) and associated wiring (deterioration of cable insulation)
- proximity to live exposed 1500 V dc and the risk of flashovers to the 1500 V dc circuits.

Termination of the wiring shall be by screwed connections using pre-insulated crimp pin connectors. All wiring shall be flexible and multi-stranded and rated to withstand a test voltage of 1.5 kV RMS to frame for 1 minute and 5 kV RMS to 1500 V dc circuits for 1 minute. The terminal area shall be appropriately shielded from any heat generating components to reduce the risk of heat damage over the long term.

9.8.3 Thermal model

A theoretical electrical or thermal model of the rectifier shall be provided including a derivative format suitable for computer simulation. The model shall be based on inputs of load current and cubicle air temperatures. The model shall incorporate diode, heat sink and any other relevant temperature time constants required to accurately simulate heat sink and diode junction temperatures and limits. The model shall be suitable for implementation in spreadsheet format such as Microsoft Excel.

The ambient air temperatures at inlet air and the outlet air will be required as a minimum to represent the ambient air temperature in the model. The thermal time constants of the sensors shall be taken into account.

The manufacturer shall validate the thermal model against results from the temperature rise tests up to 2 pu current as specified in Section 12.2.5.

9.8.4 Temperature calibration

The temperature transducers fitted to provide for remote monitoring of top and bottom cubicle air temperatures shall be positioned to ensure correct tracking with the theoretical calculations of the diode temperature and heat sink temperature. This shall be confirmed by the temperature rise tests as specified in Section 12.2.5.

9.9 1500 V negative isolator

A single pole, single way negative isolator to allow complete isolation of the rectifier from the negative return path shall be provided. The isolator shall meet the electrical characteristics specified in Table 4.

A hinged isolator switch operated by an insulated stick is preferred for simplicity, but a switch is acceptable. The isolator shall be placed in a separate compartment within the rectifier power cubicle such that the isolator can only be accessed through a separate lockable door.

The negative isolator shall have the following electrical indications:

- isolator access door open interlock signal provided by a single voltage free changeover contact, suitable for making and breaking up to 100 mA in a 125 V dc circuit
- one isolator position signal in the fully closed position and another for the isolator in the fully isolated (open) position.

A visual means of confirming the isolator position shall be provided by direct observation or other suitable method.

The control wiring from the isolator door and isolator position shall be terminated in the marshalling cubicle. The contacts shall be suitable for making and breaking up to 100 mA in a 125 V dc circuit. The contacts shall be suitable for switching relay coils and similar inductive loads.

If a negative isolator is required to be procured as a stand-alone item the following requirements shall apply:

- be provided in an IP54 rated enclosure as specified in AS 60529 with all interlocks, viewing windows, lockable doors as detailed in the immediately preceding bullet points
- comply with the electrical characteristics specified in Table 3
- the marshalling terminals associated with voltage and current measurement, negative isolator position and access door interlock signals shall be in a separate accessible compartment
- the requirement for voltage and current measurement shall be specified in the RFT
- the 1500 V dc connections shall be in accordance with Section 9.4.3 unless stated otherwise in the RFT.

9.10 Cubicle

9.10.1 General

The rectifier power cubicle shall be in accordance with the critical dimensions to enable interchangeability with existing rectifiers as shown in EL 0214515. The overall design shall minimise the build-up of dust within the rectifier. In some previous designs dust has been a particular problem in the area of the auxiliary fuses and surge suppression circuits that have formed a large horizontal surface that is not easily accessible for cleaning.

9.10.2 Panels and doors

All panels, including doors, shall be constructed of mild steel plate with robust steel framework sufficiently braced to prevent warping and twisting. Panels shall be made removable where access is required for maintenance of internal components. The doors shall be fitted with removable pin hinges and locking handles.

The completed cubicle shall be rated as IP2X as specified in AS 60529. This rating need not apply to the top surface of the rectifier, provided the safety clearances specified in Section 9.4.2 are met.

9.10.3 Installation

The rectifier power cubicle shall be installed on insulating material rated at 1500 V dc to ensure that the rectifier frame is electrically isolated from the main substation earth. The insulating material is nominally a 3 mm thick nylon sheet Delrin or similar material. The insulating material is fitted in situ to reduce the risk of damage.

9.10.4 Door and panel bonding

All surrounding metal enclosures, including doors, shall be bonded to the supporting framework of the rectifier. The frame shall be connected to the rectifier frame leakage device. After installation of the rectifier the installer shall provide a connection to the substation earth system via the frame leakage device, see Section 9.5 for further details of rectifier frame leakage.

9.10.5 Access

The cubicle shall be configured to provide a ready maintenance access to all parts. In particular, the cubicle shall be possible to clean or replace the following items without first removing any other item:

- diode assemblies
- surge suppression network

- auxiliary output fuses
- current transducer
- voltage transducer
- temperature transducers
- positive
- negative output connections.

9.10.6 Lifting points

Provision shall be made for slinging the cubicle complete with all equipment installed.

9.10.7 Labelling

All doors and removable panels shall be fitted with a sign that reads 'DANGER HIGH VOLTAGE' if it contains exposed 1500 V dc or 1500 V dc conductors. Refer to TS 03741 for signage details.

A notice shall be fitted to the front of the power cubicle listing all points of isolation required to make the equipment safe to work on. This shall include the following:

- the HV ACCB, 1500 V DCCB, and 1500 V dc negative isolator
- if the LV changeover arrangement is not fail-safe regarding back-feed or has bypass switches provided then this shall also be included
- the point of isolation for any control or other auxiliary circuits that are present in the power cubicle.

The negative isolator shall have a warning notice fitted to the access door that reads 'WARNING – OPENING THIS DOOR WILL TRIP THE 1500 V DCCB'.

9.10.8 Colour

The outside surfaces of the rectifier cubicle shall be painted storm grey, colour number N42 in accordance with AS 2700.

The inside surfaces shall be painted white, colour number N14 in accordance with AS 2700.

Alternate colours are subject to approval of PAM.

The internal and external surfaces shall be prepared and the coating applied strictly in accordance with the manufacturer’s instructions. The preparation and method of application for the finish shall aim to ensure the rectifier is corrosion free for its design life.

9.11 Marshalling cubicle

A marshalling cubicle shall be provided for the connection of instrumentation, control wiring, 125 V dc wiring and associated equipment. The purpose of this area is to act as an interface for the internal wiring and external wiring to ensure the isolation of the 1500 V dc components within the rectifier power cubicle.

The 125 V dc supply is not a filtered supply and may contain harmonics and spikes which can affect connected equipment. The manufacturer shall install a filter if required to ensure the supply is suitable for any connected equipment.

Allowances shall be made for the external wiring to enter from either top or bottom. All wiring shall be terminated on standard DIN rail terminals. The terminals shall be clearly labelled.

All equipment within the marshalling cubicle shall be clearly labelled.

The terminations for the internal wiring shall allow for appropriate insulation needed to satisfy the requirements due to any 1500 V dc rating or temperature conditions from devices such as the negative isolator, current, voltage and temperature transducers. For more information refer to TS 03821 and TS 00011.

9.12 Marshalling cubicle light

A light shall be provided in the marshalling cubicle. The light shall be activated when the door is open and deactivated when the door is closed.

The electrical supply for the light shall be from the 240 V ac substation distribution board. At certain existing locations, the supply is 220 V ac which will be advised in the RFT. Terminals shall be provided in the marshalling cubicle with appropriate cover and warning labels.

9.13 Rating plate

A rating plate in accordance with the requirements of AS 60146.1.1, shall be firmly attached on the outside of the rectifier enclosure.

In addition to the requirements of AS 60146.1.1, the rating plate shall also include the TfNSW specification number and version.

10 Human factors

The rectifier shall be designed in accordance with the human factors principles outlined in TS 04978.

The design of the rectifier shall allow for good access and visibility to items that require access for operation and maintenance. The design shall take into account the following:

- location and height of terminals and equipment within the marshalling cubicle
- location, visibility and legibility of signage
- access to rectifier components for maintenance
- negative isolator height and access for manual operation
- size and height of negative isolator viewing window
- safe handling of removable panels
- sufficient lighting levels.

11 Interface equipment

Section 11.1 to Section 11.6 contain general descriptions of items that interface with the power cubicle.

11.1 1500 V harmonic filter

A harmonic filter is provided to reduce the telephone form factor of the output voltage from the substation to not more than 0.005 when the rectifier is operating at full load or at the overloads specified.

The harmonic filter is connected directly to the positive 1500 V dc bus and the main negative bus.

11.2 Rectifier transformers

The rectifier transformer has two secondary windings, one connected in star and one connected in delta, each rated at 600 V ac. The vector group is Yy0d1. The transformer MVA rating, primary voltage and impedance voltage shall be detailed for each individual location.

11.3 Negative reactor

A series negative reactor is provided to limit the rate of rise of 1500 V dc fault currents close to the traction substation. The negative reactor shall typically have an inductance of 0.5 mH.

11.4 Auxiliary transformer

A substation auxiliary transformer (600/415 V, three-phase) is provided for the supply of substation auxiliary functions. The primary terminals of the auxiliary transformer shall be connected to the ac terminals of the delta winding (the winding closest to the negative) via fuses. See Section 9.6 for information about the connection between the rectifier and auxiliary transformer.

The neutral point of the secondary winding of the auxiliary transformer is connected to the substation earth mat.

11.5 HV alternating current circuit breaker

The maximum fault level on the TfNSW heavy rail passenger network within the metropolitan rail area is 1500 MVA dc for a three-phase symmetrical fault. The fault level at the rectifier is limited by the transformer impedance and is approximately 35 MVA.

An HV ACCB with instantaneous overcurrent and earth leakage protection (primary and backup) is set to operate at approximately five times full load of the rectifier. The ac clearing time may be as high as 0.15 s for a dc fault condition.

Operation of this protection trips the HV ACCB.

11.6 1500 V dc circuit breaker

A rectifier 1500 V DCCB which is single pole, polarised and has been designed specifically for use on a 1500 V dc traction duty is provided. The DCCB is self-contained with its own control equipment and is set at approximately 1000 A reverse current (detecting current flowing towards the rectifier) but can be set at up to 3000 A maximum.

12 Tests

12.1 General

All semiconductor devices and stacks and other components of the rectifier equipment shall be routine tested before assembly.

In equipment tests, the assembly and other items of equipment may be tested separately if this is more convenient. When tested separately the stack or assembly shall be supplied from a transformer with a connection equivalent to that specified in this document.

12.2 Routine tests

12.2.1 General

Each rectifier shall be subject to the routine tests specified in Section 12.2.2 to Section 12.2.6 and in accordance with AS 60146.1.1. All semiconductor devices and stacks and other components of the rectifier equipment shall be routine tested before assembly.

The assembly and other items of equipment may be tested separately if this is more convenient for equipment tests. When tested separately, or if the transformer is not a part of the contract, then the stack or assembly shall be supplied from a transformer with a connection equivalent to that specified in this specification.

12.2.2 Insulation test

An insulation test in accordance with Section 4.2.1 of AS 60146.1.1–2002 shall be carried out to verify the correct state of insulation of the complete assembled unit. An insulation test voltage of at least 5 kV RMS shall be used, with a preference for 8 kV RMS to be used. Test method and results shall be provided to TfNSW.

12.2.3 Light-load and functional test

The light-load test specified in Section 4.2.2 of AS 60146.1.1–2002 shall be carried out to verify that the equipment is correctly connected and that its static control properties fulfil the requirements of this specification.

12.2.4 Rated current test

The rated current test specified in Section 4.2.3 of AS 60146.1.1–2002 shall be carried out to verify that the equipment operates satisfactorily at rated current.

12.2.5 Temperature rise test

A temperature rise test consistent with the type test specified in Section 12.3.2 of this document shall be used to confirm the electrical or thermal model. A minimum of two overload conditions shall be checked. See Section 9.8.3 of this document for requirements of the thermal model to be validated by this temperature rise tests.

12.2.6 Power loss determination

The power loss determination specified in Section 4.2.4 of AS 60146.1.1–2002 shall be obtained by direct measurements using method A1, B or C as specified in Section 6.1 of SA TR IEC 60146.1.2:2024.

12.3 Type tests

12.3.1 General

One rectifier of each rating shall be subject to the type tests set out in Section 12.3.2 and Section 12.3.3 of this document and in accordance with Section 4.2 of AS 60146.1.1–2002.

12.3.2 Temperature rise type test

The temperature rise test specified in Section 4.2.5 of AS 60146.1.1–2002 shall be carried out to verify the design intention of the cooling system. The temperature rise test shall also be used to confirm the electrical or thermal model described in Section 9.8.3 of this document.

12.3.3 Overcurrent capability test

The overcurrent capability test specified in Section 4.2.12 of AS 60146.1.1–2002 shall be carried out to verify the overload ratings up to 2 pu in accordance with TS 03873.

The temperature of any connection, other than the connection of the diode to the heat sink, shall not exceed the guaranteed value.

13 Data set associated with the equipment

The following data shall be supplied by the manufacturer and maintained for the rectifier power cubicle and negative isolator:

- information and drawings – all drawings shall conform to the requirements of TS 01547.1
- technical schedule – the manufacturer shall supply the information listed in Appendix C, rectifier power cubicle and negative isolator
- test results.

This data shall remain the property of TfNSW. Appendix B provides further details of the data that shall be provided.

14 Integrated system support requirements

14.1 General

The rectifier power cubicle 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 rectifier power cubicle. This includes the following:

- specifying maintenance requirements

- spares support (this includes the availability of spares – timeframe, where they are held, how long manufacturer will guarantee supply)
- operations and maintenance manuals
- training
- support equipment and tooling.

The integrated support requirements are a significant deliverable in the procurement of new semiconductor 12 pulse series bridge rectifier power cubicle units. Manuals, training, documentation and other support deliverables shall be in accordance with TS 03742.

14.2 Operation and maintenance manual

Operation and maintenance manuals shall be provided for the equipment in accordance with the requirements of TS 03742.

The following additional content shall also be included:

- photographs of the complete rectifier power cubicle from all sides
- photographs showing all 600 V ac and 1500 V dc (positive and negative) cable interfaces
- photographs showing the negative isolator and associated position indicators
- photographs showing the negative isolator access door and interlock switch
- photographs showing the frame leakage relay and associated earth and rectifier frame connections
- photographs of the inside of the marshalling cubicle
- detailed step by step instruction for removing and installing diodes with appropriate photographs.

All operation instructions and associated descriptions of equipment shall be accompanied by colour photos of the actual equipment installed on the rectifier that is being described.

Appendix A Whole-of-life cost (normative)

Appendix A is provided for TAOs so they can assess the whole-of-life cost and shall take that into account in accordance with TS 01505.

The selection of the most suitable rectifier power cubicle should be made on the basis of minimising the whole-of-life cost. The following factors should be considered when determining this:

- 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
- electrical losses
- initial purchase price
- lifetime of equipment
- reliability and cost of consequential damage after failure
- cost of optional tests.

If this rectifier power cubicle has not previously been type approved by the PAM in accordance with TS 06178, the costs for this process shall be included in the whole-of-life cost.

Appendix B Data set associated with the equipment (normative)

Sections B.1 to B.4 provide details of the data that shall be supplied by the manufacturer and maintained for the 1500 V dc rectifier power cubicle and negative isolator. This data remains the property of TfNSW.

B.1 Drawings and information

All drawings shall conform to the requirements of TS 01547.1. The following drawings are required.

- schematic and termination diagrams as follows:
  - main power circuit schematic diagrams with all diodes, resistors, capacitors and other components
  - LV, control and instrumentation schematic diagram
  - main power termination diagram (material of main termination palms to be specified)
  - LV, control, instrumentation and SCADA termination diagrams
- arrangement drawings as follows showing:
  - all external details including ac and dc connection details and all relevant dimensions, details of door dimensions and associated opening direction
  - internal arrangement detailing main busbars and associated components, location of auxiliary fuses, negative isolator details, LV terminals, location of air temperature sensors
- layout drawing showing physical positions of all major components and including a parts list and legend including the following:
  - diode and heat sink details
  - transducer details.

Full details of current, voltage and temperature transducers shall be provided.

B.2 Technical schedule

The information listed in the technical schedule of Appendix C should be completed by the manufacturer and engineering assurance provided by the TAO for each rectifier power cubicle and negative isolator.

B.3 Life cycle costing

All the data and assumptions pertaining to the determination of the whole-of-life cost calculations shall be recorded by the TAO. See Appendix A for further details.

B.4 Test results

The results of all tests, including acceptance tests and periodic and corrective maintenance tests, shall be recorded and maintained.

Routine tests certificates showing the results of each test performed shall be supplied in English and maintained for the life of the equipment.

Type test certificates showing the results of each test shall be supplied in English and maintained for the life of the equipment.

Test results shall be provided to TfNSW.

Appendix C Technical schedule (normative)

The information listed in this section shall be provided by the manufacturer with the tender for each rectifier power cubicle and negative isolator. The schedule provides descriptive information that shall be submitted at the time of tender.

C.1 Rectifier technical schedule

The manufacturer shall provide rectifier information listed as follows:

Rectifier details	
Name of manufacturer	
Country of manufacture	
Weight	kg
IP rating	
Output voltage at full load	V
Rated Power	W
Current rating at full load voltage	A
Total number of diodes used in each rectifier	
Number of diodes connected in parallel per arm	
Number of diodes connected in series per arm	
Surge protection measures provided to cover hole storage effects as well as system and switching surges	
Are surge diverters provided across the dc terminals?	
Minimum clearance in air between earthed metal work and uninsulated 1500 V dc conductors	mm
Minimum creepage distance between earthed metal work and uninsulated 1500 V dc conductors	mm
Material over which the above-mentioned creepage distance applies	
Minimum clearance between uninsulated phase conductors connected to rectifier transformer secondary	mm
Minimum clearance to earth of uninsulated phase conductors connected to rectifier transformer secondary	mm
Clearance required above cubicles for satisfactory circulation of cooling air	mm
Rectifier frame leakage prospective fault current capability	kA s

Rectifier details	
Insulation test voltage (see Section 12.2.2)	
600 V ac busbar palm material	
1500 V dc positive and negative busbar palm material	
1500 V cable entry (top or bottom)	

Rectifier and Isolator dimensions	
Rectifier dimensions (W x D x H) (including marshalling cubicle and negative isolator cubicle)	mm x mm x mm
Extreme height from ground level	mm

Rectifier losses:	
Losses at 5% full load	W
Losses at 25% full load	W
Losses at 50% full load	W
Losses at 100% full load	W
Losses at 150% full load	W
Losses at 200% full load	W
Forward voltage drop of the rectifier	
Voltage drop at 5% full load	V
Voltage drop at 25% full load	V
Voltage drop at 50% full load	V
Voltage drop at 100% full load	V
Voltage drop at 150% full load	V
Voltage drop at 200% full load	V

Diode details:	
Diode manufacturer	
Manufacturer’s type number	
Creepage distance over diode insulation	mm
Type of junction	alloyed or diffused
Maximum allowable continuous operating temperature of junction	ºC
Anticipated failure rate of diodes	per year
Heat sink type number	
Material used for heat sink	

Diode details:	
Has a type test been carried out on the same type of equipment	
Diode rating	
The data listed below is for a junction temperature of	ºC
Rated 120° conduction average forward current of the diode IF(AV)	A
Rated voltage of the diode UF @ IF	 V A
Rated repetitive peak reverse voltage of the diode (URMM)	V
Rated non-repetitive peak reverse voltage of the diode. (URSM)	V
Describe precautions taken to ensure that diodes connected in series operate within their reverse voltage rating.	
Describe precautions taken to ensure that diodes connected in parallel operate within their forward current rating.	

Temperature rise:		
Ambient temperature for which the following temperatures apply		ºC
Rated load	at *base ºC	at junction ºC
Rated load + 150% for 2 hours		
Rated load + 200% for 30 minutes		
Rated load + 300% for 1 minutes		
Rated load + 400% for 10 seconds		

* The base of the diode will be the part of the case used for temperature measurements during the temperature rise tests.

C.2 Negative isolator technical schedule

Negative Isolator details	
Manufacturer	
Model	
Weight	kg
IP rating	
Nominal voltage (U_n)	kV

Negative Isolator details	
Rated voltage (U_{Ne})	kV
Rated insulation voltage (U_{Nm})	kV
Rated impulse voltage to earth (U_{NiA})	kV
Rated impulse voltage across isolating distance (U_{NiB})	kV
Power frequency withstand voltage to earth (U_aA)	kV
Power frequency withstand voltage across the isolating distance (U_aB)	kV
Rated service current (I_{Ne})	kA
Rated short time withstand current (I_{Ncw})	kA
Rated short circuit current (I_{NSS})	kA/s
Overload ratings Rated load + 150% Rated load + 200% Rated load + 300% Rated load + 400%	 hours minutes minutes seconds
Electrical clearance:1500 V dc to earth	mm
Electrical clearance across the isolating distance	mm
Electrical clearance creepage distance	mm
Method of determining position of isolator (include details of how voltage isolation is achieved for auxiliary contacts)	
Number and rating of auxiliary contacts	
Method of operation	

C.3 Instrument technical schedule

Instrumentation – 1500 V dc current measurement:	
Method of measuring current	
Manufacturer of transducer	
Model of transducer	
Continuous current rating	A
Isolation rating	kV
Accuracy	
Output range	
Auxiliary supply required? (If yes, include requirements and if any filtering is provided)	

Instrumentation – 1500 V dc voltage measurement:	
Method of measuring the voltage	
Manufacturer of transducer	
Model of transducer	
Voltage rating	V
Isolation rating	kV
Output range	
Auxiliary supply required? (If yes, include requirements and if any filtering is provided)	

Instrumentation – Heat sink temperature measurement:	
Method of measuring the heat sink temperature	
Manufacturer	
Model	
Isolation rating	kV
Output range	
Auxiliary supply required? (if yes, include requirements)	

Instrumentation – Air temperature measurement:	
Method of measuring the air temperature	
Manufacturer	
Model	
Isolation rating	kV
Output range	
Auxiliary supply required? (if yes, include requirements)	

C.4 Rectifier reliability data

Rectifier reliability data (use separate sheet if necessary):		
Design life		Years
Failure modes (for early, normal life and wear out periods):	a)	
	b)	
	c)	

Mean operating hours between failures:	a)	
	b)	
	c)	
Time to repair:	a)	
	b)	
	c)	

C.5 Drawings and information to be submitted with the tender

In addition to the technical schedule, the following information shall be submitted with the tender:

- Fully dimensioned outline drawing showing top, bottom, elevation and end views. The general arrangements and layouts shall be adhered to in the final design unless written approval is obtained from PAM.
- Technical datasheets for negative isolator, negative isolator position indicators, current and voltage measurement devices, diodes, air temperature measurement devices and frame leakage relay.
- Reference list where similar equipment has been installed and is under satisfactory operation for the past two years as a minimum.
- Details of any departures from the requirements of this specification.
- Any special requirements required for the safe delivery of the rectifier to the specified site. These costs shall be provided separately at the tender stage.

Appendix D Information for request for tender (informative)

This appendix contains the information to be provided with the RFT at the time of tender and by the tenderer with the submission.

See Appendix C for the requirements for the tenderers to complete and submit with the technical schedule.

For procurement of rectifier and negative isolators relevant site-specific information and technical information should also be made available to tenderers.

Table 6 provides a list of technical details of the rectifier power cubicle and negative isolator that should be included in the RFT.

Table 6 – Technical details to include in the RFT

Rectifier item	Technical details to include in the RFT
600 V ac connection type from rectifier transformer	Indicate whether cable or busbar connected
600 V ac cables to auxiliary transformer cable entry	Indicate whether top or bottom entry
1500 V dc positive and negative cable entry	Indicate whether top or bottom entry
Auxiliary ac voltage	Indicate whether 415 V ac or 220 V ac (unearthed)
Auxiliary dc voltage	Indicate whether 125 V dc or 50 V dc
Auxiliary transformer	Indicate whether: • Auxiliary transformer is fed from the rectifier transformer or another source • Fuse size if it is fed from the rectifier transformer

Table 7 provides site specific information to be considered for inclusion in the RFT.

Table 7 – Site specific information to consider including in the RFT

Site specific information	Information to include in the RFT
Site specific limitations on size or arrangement	Indicate whether there are size limitations imposed by surrounding infrastructure
Access and transportation limits	Access road weight limit Maximum road width Maximum standard height above road