TRANSNET
freight rail

A Division of Transnet SOC Limited

TECHNOLOGY MANAGEMENT

SPECIFICATION

3kV RECTIFIER FOR TRACTION SUBSTATIONS

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1.0 SCOPE

1.1 This specification covers Transnet Freight Rail's requirements for the design, manufacture, supply and installation of 3 kV Direct Current (DC) rectifier units for DC traction substations.

2.0 STANDARDS AND PUBLICATIONS

2.1 Unless otherwise specified all materials and equipment supplied shall comply with the current edition of the relevant SANS, IEC or Transnet Freight Rail's publication where applicable.

2.2 The following publications are referred to in this specification:

2.2.1 INTERNATIONAL ELECTROTECHNICAL COMMISSION

IEC 60051: Direct acting indicating analogue electrical-measuring instruments and their accessories.

IEC 60146-2: Semiconductor converters - Part 2: Self-commutated semiconductor converters including direct dc converters.

2.2.2 SOUTH AFRICAN NATIONAL STANDARDS

SANS 1019: Standard voltages, currents and insulating levels for electrical supply.

2.2.3 TRANSNET FREIGHT RAIL

BBB 2721: AC Primary Circuit Breaker Control Panel and AC/DC Distribution Panel for 3kV Traction Substations.

BBB 5452: Transnet Freight Rail's Requirements for the Installation of Electrical Equipment for 3kV DC Traction Substations.

BBD5994: Technical Documentation Management Policy.

BBF3690: Transnet Freight Rail - Electrical Safety Instructions 2012.

2.3 Any items offered in accordance with other standards will be considered at the sole discretion of Transnet Freight Rail. The tenderer shall supply full details stating where the item differs from these specifications as well as supplying a copy (in English) of the recognised standard specification(s) with which it complies.

3.0 TENDERING PROCEDURES

3.1 Tenderers shall indicate clause by clause compliance with the specification. This shall take the form of a separate document listing all the specifications clause numbers indicating the individual statement of compliance or non-compliance. This document can be used by tenderers to elaborate on their response to a clause.

3.2 A statement of non-compliance shall be motivated by the tenderer.

3.3 Tenderer shall submit for each type of rectifier a filled in form as per Appendix 1.

3.4 Tenderers shall submit descriptive literature consisting of detailed technical specifications, general constructional details and principal dimensions, together with clear illustrations of the equipment offered.

3.5 Failure to comply with clauses 3.1, 3.2, 3.3 and 3.4 could preclude a tender from consideration.

4.0 SERVICE CONDITIONS

4.1 ATMOSPHERIC CONDITIONS

The equipment shall be designed and rated for installation and continuous operation under the following conditions:

Altitude:	0 to 1800m above sea level.
Ambient temperature:	-10°C to +55 °C.
Relative humidity:	10% to 90%.
Lightning Conditions:	15 ground flashes per square kilometre per annum.
Pollution:	Heavily salt laden or polluted with smoke from industrial sources.

4.2 MECHANICAL SERVICE CONDITIONS

4.2.1 The rectifiers are installed in substations next to or within close proximity of railway tracks and will be subjected to vibration from the trains.

4.3 ELECTRICAL SERVICE CONDITIONS

4.3.1 INPUT VOLTAGE

4.3.1.1 The rectifier AC input voltages for six-pulse configuration is in the order of 2450V AC per phase. For 12-pulse configuration the AC input voltages can be in the order of 1120V to 1375V phase to phase.

4.3.1.2 The rectifier receives its supply from a 3.3 MVA or 5 MVA rectifier transformers (and 6 MVA where transformers are replaced).

4.3.2 OUTPUT VOLTAGE

4.3.2.1 The nominal busbar output voltage rating of the system is 3150 Volts but can vary between 2400 V DC and 3900V DC.

5.0 DESIGN OF EQUIPMENT

5.1 The rectifier unit and its associated control equipment should be built up to form an independent unit.

5.2 The rectifier design shall be suitable for operation for existing or new traction substations, the details of which shall accompany this specification.

5.3 For multiple unit substations it shall be possible for each unit to operate completely independently of each other.

5.4 For single transformer, multi-group arrangements, it shall be possible to isolate and switch off one group without affecting the other group.

5.5 Six or twelve pulse operation is used depending on the configuration of the transformers.

5.6 This specification includes all the required control and protection circuits which shall be installed and wired to existing substation control panels by the supplier.

5.7 The control circuitry for tripping and indication purposes shall operate at 110 volt DC.

5.8 RATINGS

5.8.1 The DC output of the equipment shall be rated at 3 MW, 4.5 MW, 5 MW or 6 MW full load continuously with overload ratings related to full load as follows:

2 x full load for 30 minutes
3 x full load for 1 minute
3.5 x full load for 10 seconds.
4.25 x full load instantaneous tripping.

5.8.2 The equipment shall withstand a short circuit for 200 milli-seconds.

5.8.3 The ratings of the rectifier with its configuration shall be displayed on a silkscreen label fixed on the rectifier unit.

5.9 The rectifiers and associated equipment shall be designed to minimise any tendency to resonate or to produce high voltage surges when operating in conjunction with DC smoothing equipment.

5.10 Lightning, transients, surges and tripping are present in the substation environment.

6.0 INSULATION LEVELS

6.1 Insulation levels for high voltage equipment shall be in accordance with the recommendations of SANS 1019.

6.2 The nominal 1.5kV and 3kV insulation to earth shall be so designed that the complete rectifier assembly shall be able to withstand a test voltage of 10.5kV, 50Hz AC for one minute.

6.3 Where PVC trunking is used for the routing of cables it shall be so installed that there can be no danger of a flash over or tracking occurring between the trunking and high voltage circuitry.

7.0 CLEARANCES AND CREEPAGE DISTANCES

7.1 The following minimum safety clearances shall be maintained:

For the nominal DC system voltage, the minimum air clearance shall not be less than 150mm from any conductor or metal normally live and ground level.

7.2 Ribbed insulators and standoff bushings shall be used for 3kV DC and shall have a creepage distance of not less than 239 mm.

8.0 RECTIFIER UNIT

8.1 RECTIFIER DESIGN REQUIREMENTS

8.1.1 The silicon rectifier diode assemblies shall comply with SANS 60146-2.

8.1.2 The rectifier unit shall comprise silicon semiconductor-diodes and be of the hockey puk capsule type.

8.1.3 All materials used shall be flame retardant.

8.1.4 To prevent flashovers no insulation material shall be used between rectifier branches. The minimum air clearance of 150mm is required between diode modules as well as between diode modules and any earthed metal.

8.1.5 The minimum distance between the incoming supply phases to the rectifier shall not be less than 150mm.

8.1.6 It is required that the equipment offered be designed to remain in service in the event of any individual diode in a branch becoming defective.

8.1.7 The rated repetitive peak reverse voltage of a series connected branch of diodes shall be such that should a diode in that branch become defective, the rated repetitive peak reverse voltage of the remaining diodes will be at least twice the value of the applied reverse voltage. The peak inverse voltage shall be not less than 4000V DC or higher for a 24 diode bank.

8.1.8 The creepage distance across the resistor capacitor (RC) circuit components shall be commensurate with the creepage distance across the diode insulation.

8.1.9 Tenderers shall provide a full description of the over voltage and surge protection circuits offered illustrating how this circuit has been designed.

8.1.10 Each rectifier unit shall be provided with a DC voltmeter, range 0-4 000 volts and a DC ammeter range 0-4000 amperes. These shall be mounted on the front of the rectifier unit.

8.1.11 The DC voltmeter shall be connected to the more negative side of the voltage divider.

8.1.12 For the DC ammeter a 4000 ampere 50 mV shunt shall be fitted on the negative busbar of the rectifier.

8.1.13 The DC voltmeter and ammeter shall be class 1.5 or better. The dimensions of the analogue face of the meters fitted on the rectifier unit shall not be less than 144mm x 144mm with a 90 degree display.

8.1.14 A high voltage fuse and potential divider shall be provided for the voltmeter.

8.1.15 The potential divider shall consist of not less than ten separate vitreous enamel resistance elements connected in series.

8.1.16 The DC output of the rectifier unit shall be protected from external voltage transients by means of fused resistance capacitance parallel metal oxide varistor circuitry. The fuse shall be fitted with a trip contact, which can be utilised for indication and control.

8.2 DIODES

8.2.1 For 3 MW and 4.5 MW rectifiers the Westcode type W2899MC480 and INFINEON (EUPEC) D1809 N40 or N46 diodes (exact equivalent or approved types) shall be used.

8.2.2 For 5 MW and 6 MW rectifiers the Semikron ZP 3000/68 diodes (exact equivalent or approved types) shall be used.

8.2.3 Proof of origin of the diodes and certified test certificates shall be supplied with the diodes.

8.2.4 The forward voltage drop of the diodes shall be within ± 5% variations.

8.2.5 Tenderers shall submit fully detailed data sheets of the type of diode offered.

8.2.6 Each individual diode shall form an integrated module with its heatsink, snubber circuit and parallel voltage- equalising resistor circuit. The module shall contain no connection wires or lugs. All connections shall be made directly through the mounting of the snubber printed circuit board busbar terminations. The design of the module shall enable it to be removed within 10 minutes, without disturbing any other modules.

8.2.7 The rectifier design shall be such that only the diode module securing bolts need to be removed for replacement of a module. No busbars or other parts shall obstruct the removal of the diode module.

8.2.8 For identification of the diode polarity, the rectifier symbol shall be clearly marked on the heatsink module and on the diode.

8.2.9 Tenderers shall indicate the recommended intervals between the testing of diodes and their RC snubber components so as to establish their soundness.

8.3 SNUBBER (RC) AND VOLTAGE EQUALISING CIRCUITRY

8.3.1 The capacitors and resistors employed in the snubber RC circuits shall be of the highest quality and shall be suitably rated for high voltage applications encountered. Vitreous enamel wire wound resistors or similar shall be used and high voltage suitable capacitors shall be used.

8.3.2 If standoff posts are used to support sensing circuits they shall be securely fixed to the main diode module by means of lock washers and nuts to ensure that no sparking occurs due to poor contact.

8.4 DIODE MONITORING EQUIPMENT

8.4.1 DIODE SENSOR TRANSMITTER MONITORING MODULE

8.4.1.1 Sensing circuitry shall be incorporated to monitor each individual diode for open or short circuit conditions.

8.4.1.2 Specific attention shall be given to the protection of the diode monitoring circuit boards in the event of the diode going open circuit and destroying the monitoring modules.

8.4.1.3 Protection circuitry shall be shall be provided for each sensor module.

8.4.1.4 The sensor module shall be powered from the snubber RC circuit of the diode and shall be designed so as not to change the characteristics of the RC circuit across which it is connected.

8.4.1.5 The snubber RC circuitry, and the diode sensing circuitry, shall be removable as a unit with the diode module when the diode module is removed for replacement or repair.

8.4.1.6 The components used to manufacture the diode sensor transmitter module shall be of the highest quality.

8.4.1.7 If resistors are employed they shall be vitreous enamel insulated or similar and shall withstand at least 700 volts across them.

8.4.1.8 The diode sensing circuit board shall be removable from the diode module as an individual circuit board for repair or replacement.

8.4.1.9 The diode sensing circuit board shall be so constructed that it will be protected against reverse polarity on installation after repair or replacement.

8.4.1.9.1 The output signal from the diode sensor transmitter board shall be fibre optic transmitted. Wire conductors are not acceptable.

8.4.1.9.2 Diode monitoring systems utilising Programmable Logic Controllers (PLC) is not acceptable.

8.4.2 RECTIFIER DIODE MONITORING PANEL AND DISPLAY

8.4.2.1 The rectifier unit shall be fitted with a diode monitoring panel for monitoring the condition of each diode.

8.4.2.2 Each diode shall be clearly numbered on the front display cover of the diode monitoring panel as well as on the diode module. The markings shall be silk screened engraved or similar.

8.4.2.3 The panel shall be fitted with Light Emitting Diodes (LED's) to indicate the condition of the diodes. The LED's shall be green for a healthy diode and red for an open circuit or short circuit diode.

8.4.2.4 A remote reset switch or button to reset the LED's and the diode monitoring panel shall be fitted in the primary circuit breaker control panel.

8.4.3 ELECTRONICS

8.4.3.1 All printed circuit boards shall be constructed from high quality fibreglass material.

8.4.3.2 All printed circuit boards shall slide in high quality edge connectors and shall be easily removed for replacement or repairs.

8.4.3.3 All printed circuit boards with its components shall be coated for protection against moisture, corrosion and dust.

8.4.3.4 Each printed circuit board shall be polarised to prevent the card from being plugged into the wrong socket and to prevent the card from being inserted upside down.

8.4.3.5 The control unit shall be designed to fail to safe in the event of power supply failure or printed circuit board failure. Contacts shall be provided which can be utilised for lockout signals.

8.4.4 POWER SUPPLY SYSTEM

8.4.4.1 The power supply shall be of the switch mode design and shall be able to operate within the range of the voltages available in the substation.

8.4.4.2 The power supply as well as the remainder of the unit shall be extensively protected from lightning, transients and surges. Extensive use of gas arresters, inductors and capacitors will be required.

8.4.5 FIBRE OPTIC MONITORING BOARD

8.4.5.1 The annunciator shall be fitted with fibre optic receivers for signals transmitted from the diode sensor transmitter module.

8.4.6 INTERFACE INPUT-OUTPUT PRINTED CIRCUIT-BOARD

8.4.6.1 The diode monitoring main board shall be able to communicate the condition of the diodes by means of relay contacts.

8.4.6.1.1 Provision shall be made for one diode failure to lockout the substation with a remote flag indication and give a signal to the telecontrol system.

8.4.6.2 The relays shall function in the fail safe mode, i.e. the relays will be energised and will de-energise under faulty conditions.

8.5 COOLING

8.5.1 The rectifier unit shall be fitted cooling fans with temperature sensors for the control of the cooling fan, temperature monitoring and rectifier over-temperature protection.

8.5.2 The direct heat sink temperature sensing method shall be used with multiple sensors connected in series.

8.5.3 Two thermal control switches shall be fitted to the rectifier for the energising of the cooling fans at a temperature of 50°C. Provision shall be made to prevent the fan from cycling at the energising temperature.

8.5.3.1 Suitable fan control circuitry shall be provided by the supplier.

8.5.4 The rectifier unit shall be provided with two over temperature sensing switches which shall be set at 80°C.

8.5.5 The rectifier over temperature protection shall be used for tripping purposes. The circuitry shall be provided by the supplier.

8.5.6 The wiring from the sensors to the fan controller should be of the plastic fibre optic type and the sensors should obtain their supply from the RC circuit.

8.5.7 Fan airflow failure circuitry (vane switches) and relays shall be provided for control and indication purposes. A fan test switch which is spring loaded to the off position shall be provided and installed in the primary circuit breaker control panel.

8.5.8 Adequate measures shall be taken to ensure that the rectifier equipment does not overheat during periods of high loading. Details of the over temperature protective scheme shall be submitted with the tender.

8.5.9 Provision shall be made for adjustable current sensing to control the operation of the cooling fan(s). The fan(s) shall be energised when the main current reaches a value of 700 amps (adjustable.) The current sensing circuitry shall be sufficiently isolated and shall be installed in the primary circuit breaker control panel.

9.0 INSTALLATION

9.1 The contractor shall be responsible for the transport to site, off-loading, handling, storage and security of all material required for the installation of the rectifier unit.

9.2 The rectifier shall be installed within the substation building and shall be totally insulated from the floor by means of channel insulation or other high voltage insulating material.

10.0 EARTHING

10.1 The metal framework of the rectifier shall be connected to the existing DC earth leakage earthing system in accordance to drawing no. CEE-TBD-7. Should the existing earth strap not be suitable for re-use a new copper earth strap of least cross-section area or a stranded insulated copper conductor with a cross-sectional area of at least 95mm ^{2} shall be used.

11.0 CABLES

11.1 Armoured cables shall be used for the wiring of the cooling fans and any other external power circuitry.

11.2 All cables shall terminate in compression type glands. These glands shall be fitted with neoprene shrouds.

11.3 Screened cables and conductors shall be used for electronic screening and noise reduction techniques where required.

11.4 The fibre optic cables between the rectifier and the annunciator panel shall be protected from damage by means of conduit or trunking or other suitable means. Open fibre optic cables are not acceptable.

11.5 All cabling shall be clearly marked with high quality permanent markers. Sticker marking numbers will not be acceptable.

12.0 INTERCONNECTION OF EQUIPMENT

12.1 Suitably rated Copper or Aluminium busbars shall be used for the interconnection of the rectifier to the secondary winding of the traction transformer. The busbars between separately mounted equipment shall incorporate a degree of flexibility to avoid any over stressing of these connections due to movement caused by conductor expansion/contraction and to facilitate alignment of equipment. Sizes for AC (Copper 50X10mm and Aluminium 25X50mm) and sizes for DC (Copper 100X10mm and Aluminium 127X12.5mm).

12.2 High conductive silicon grease shall be liberally applied to all connections.

12.3 All dissimilar metal connections copper to aluminium (Cu to Al) shall be made using bi-metallic clamps that are specifically designed and manufactured to make that particular connection.
(adhoc fabricated clamps are not acceptable).

12.4 All copper connections to steel (galvanised) shall be tinned or silver coated.

13.0 INSPECTION, SITE TESTS AND COMMISSIONING

13.1 Transnet Freight Rail reserves the right to carry out inspection and any tests on the equipment at the works of the supplier/ manufacture.

13.2 Arrangements must be made timeously for such inspections to be carried out before delivery of the equipment to the client.

13.3 The contractor shall be responsible for carrying out on-site functional tests before the commissioning of the rectifier unit.

13.4 The testing of the rectifier shall include type tests for new design of rectifier units and routine tests which shall be conducted on all units. Quality Assurance labels must be mounted on the rectifier rating board.

13.4.1 The testing shall include the following: -

- Insulation tests.
- Light load tests.
- Functional tests on the associated control equipment and circuitry of the rectifier.
- Temperature rise tests i.e. temperature measurements on diode heatsinks. Maximum temperature rise shall not exceed 75° C.
- Checking of auxiliary and protective devices and control equipment.
- Rated output tests.
- Overcurrent capability test.
- Measurement of output voltage.
- Power loss determination.

13.4.2 Functional Acceptance by the Maintenance Manager of satisfactory completion of on-site tests in no way relieves the contractor of his obligation to rectify defects which may have been overlooked or become evident at a later stage.

13.5 Commissioning will only take place after all defects have been rectified to the satisfaction of the Maintenance Manager.

13.6 Commissioning will include the energising of equipment from the primary isolator to the track feeder circuits. The contractor must prove the satisfactory operation of equipment under live conditions.

13.7 On completion of commissioning the contractor will hand the equipment over to the Maintenance Manager in terms of the relevant engineering instructions.

14.0 DRAWINGS, INSTRUCTION MANUALS AND SPARES LISTS

14.1 Drawings, instruction manuals and spare parts catalogues shall be supplied in accordance with Transnet Freight Rail's specification BBD5994.

14.2 All drawings (paper prints) shall be submitted to the technical officer for approval. No Construction or manufacturing activity will be allowed prior to the associated drawings having been approved by the technical officer.

14.3 The tenderer shall supply three copies of an instruction/maintenance manuals, schematic diagrams, diode application notes and protection and filter ratings.

14.4 The contractor shall submit details of spares required in accordance with specification BBD5994.

14.5 All spares recommended for normal maintenance purposes that are not available locally (requires importation) must be highlighted.

15.0 SPECIAL TOOLS AND/OR SERVICING AIDS

15.1 Special tools or servicing aids necessary for the efficient maintenance, repair or calibration of the equipment shall be quoted for separately.

15.2 Tenderers shall submit detailed offers for special tools and servicing aids including all specialised equipment required for the servicing and maintenance of the equipment supplied.

16.0 TRAINING

16.1 The tenderer shall submit details with the tender of the training courses, which will be conducted by the contractor for the training of Transnet Freight Rail's maintenance staff in the operation and maintenance of the equipment supplied. The courses shall include theoretical as well as practical tuition. The date and venue of this training course shall be arranged with the maintenance manager.

17.0 GUARANTEE AND DEFECTS

17.1 The contractor shall guarantee the satisfactory operation of the complete electrical installation supplied and installed by him and accept liability for maker's defects, which may appear in design, materials and workmanship.

17.2 The guarantee period for all substations shall expire after: -

A period of 12 months commencing on the date of completion of the contract or the date the equipment is handed over to Transnet Freight Rail whichever is the later.

17.3 Any specific type of fault occurring three times within the guarantee period and which cannot be proven to be due to other faulty equipment not forming part of this contract e.g., faulty locomotive or overhead track equipment, etc., shall automatically be deemed an inherent defect. Such inherent defect shall be fully rectified to the satisfaction of the Maintenance manager and at the cost of the Contractor.

17.4 If urgent repairs have to be carried out by Transnet Freight Rail's staff to maintain supply during the guarantee period the contractor shall inspect such repairs to ensure that the guarantee period is not affected and should they be covered by the guarantee, reimburse Transnet Freight Rail the cost of material and labour.

18.0 APPENDIX 1

TECHNICAL DATA SHEET

(To be completed by Tenderer)

1.0 Rectifier ratings (MW):_____

2.0 Number of diodes per branch:_____

3.0 Type of Diode:_____

3.0 Full load current rating of diode. $I_{FRMS:}$_____

4.0 Average current rating of diode. $I_{FAVM:}$_____

4.0 Repetitive Peak Reverse Voltage of diode:_____

5.0 Surge forward current 10 milli second Sine Wave:_____

6.0 Method of cooling of rectifier:_____

7.0 Method of temperature sensing: _____

8.0 Type of insulation used for frame to floor: _____

9.0 Physical dimensions of rectifier unit:

Height: _____ Breadth: _____ Width: _____

10.0 Name of suppliers where rectifier diodes can be sourced: _____

_____

11.0 Method of correct torque adjustment for heat sinks: _____

_____

12.0 Diode test certificate attached Yes/No:_____