TECHNICAL SPECIFICATION
FOR
CATHODIC PROTECTION SYSTEM

SPECIFICATION NO.: PE-TS-XXX-510-EXXX REV. 00

BHARAT HEAVY ELECTRICALS LIMITED
POWER SECTOR
PROJECT ENGINEERING MANAGEMENT
NOIDA, UTTAR PRADESH, INDIA
SECTION - C

TECHNICAL REQUIREMENTS

FOR

CATHODIC PROTECTION SYSTEM

SPECIFICATION NO:  PE-TS-XXX-510-E001 Rev 0
1.0 GENERAL

1.01 The intent of specification is to cover the following activities for Cathodic Protection System for buried Fuel Oil [FO] System and CW System piping as per BoQ/Price Schedule:

a. Design, engineering, manufacturing, fabrication, assembly, inspection and testing at manufacturers works, proper seaworthy packing, and delivery at Chennai port,
b. Site survey and analysis related to the system,
c. Supervision of all site activities including but not limited to unpacking, execution of all associated civil works, erection, inspection, testing and commissioning, performance testing at site and handling over to the Owner / BHEL.
d. Monitoring of the system for the specified period.

Detailed activities in respect of above are listed under clause 4.0 [Scope of Work].

1.02 Detailed specifications for the equipment/work included in this specification are given in the following Annexures enclosed with this Section.

Annexure I Anodes & Backfill
Annexure II Cables, Cable Laying And Termination
Annexure III Junction Box
Annexure IV Reference Electrode & Grounding Cell
Annexure V Test Lead Point
Annexure VI Transformer Rectifier Unit
Annexure VII Thermit Welding
Annexure VIII Survey
Annexure IX Guidelines For Shipping And Sea-Worthy Packing (Spec. no. PE-TS-XXX-501-A-100)

2.0 SPECIAL INSTRUCTIONS TO BIDDERS

2.01 Wherever a material or article is specified or described by the name of a particular brand, manufacturer or trade mark, the same shall be understood as establishing the type, function and quality desired. Other manufacturers' products may also be considered provided sufficient information is furnished so as to enable BHEL to determine that the products are equivalent to those named.

2.02 Details of pipelines are indicated in the BoQ enclosed.

2.03 The Bidder is advised to visit the site in order to acquaint himself with all the necessary information such as soil conditions, transportation facilities, data of similar pipelines and underground cables & cable trench/corridor in the adjacent pipe corridor, transmission line/railway line interferences, etc. for proper design and execution of the work. Ignorance of the site conditions will not be accepted as a basis of claim for any compensation whatsoever.

2.04 The Cathodic Protection system also includes certain works related to pipelines such as provision of Insulation Joints.

2.05 The scope of work shall include monitoring services for a specified period after completion of initial operation or commissioning of Impressed Current Cathodic Protection (ICCP) system. During this period, the Vendor shall visit the site and carry out testing and measurements of the system.
parameters in presence of Owner/ BHEL to ascertain the safe and sound operation of the same. Any adjustment in the operating parameters shall be recommended to Owner/ BHEL during the course of such monitoring activity along with technical justification for the same if required. The periodicity of the visits and the period for which monitoring is required shall be informed separately to bidders.

2.06 Quantities or rating of the equipment, if mentioned in the specification, are indicative only and are minimum requirements. Bidder shall check the specified BOQ, inclusive of number and weight of anodes, rating of transformer rectifier units, size and types of cables, etc. as per the standards/ codes, practices specified and considering the basic design data / guidelines specified in this Section. Any improvement with respect to the rating, number, and size of all equipment to meet the requirements of Technical Specification shall be considered while bidding and the same shall be supplied, erected and commissioned within the quoted price.

2.07 Bidder shall note that the FO pipelines are cross-country pipelines and it shall be the responsibility of the bidder to make necessary approaches wherever required along the pipe routed to execution of work. The bidder shall also take necessary care and precautions so as not to disturb the fields or property located in the vicinity of pipeline corridor during the execution of the work.

2.08 Notwithstanding anything stated in any of the bid documents, the vendor shall have to arrange construction electrical power, water and space for vendor’s office, store, their staff, labours, service air, etc. along the pipe corridor for execution of the work. The vendor’s price shall be deemed to include all such incidental expenses on all such accounts.

3.0 DESCRIPTION OF CATHODIC PROTECTION SYSTEM

3.01 It is proposed to provide Permanent (Impressed Current) type Cathodic Protection (ICCP) system for the Fuel oil and CW system buried pipelines. For details of piping refer BoQ enclosed.

3.02 In Impressed current system, the protective current required shall be supplied by transformer rectifier (T/R) units connected to the electrical main supply and fed into the pipeline by buried impressed current anodes.

3.03 The transformer rectifier units shall be the source of power for the ICCP system. The output of T/R unit shall be automatically varied to achieve the setting of pipeline to soil potential.

3.04 Suitable measures as per international practice will be taken to mitigate any interference current and cross currents from any source.

3.05 Special protection shall be provided at cased-crossing (Road-crossing/ Rail crossing etc.). Additional permanent sacrificial anodes for casings/ carrier pipes within casings shall be provided by the vendor.

3.06 Each CP system (station) shall essentially consist of three main components:
   a. Transformer/ Rectifier stations supplying the protective current.
   b. Impressed current anodes packed with backfill.
   c. Cables between rectifier, pipeline and impressed current anodes.

3.07 Cathodic Protection (CP) stations shall be provided by the vendor in adequate numbers.

3.08 Each CP station shall comprise of sets of anode, anode junction boxes, T/R unit, 2 numbers of permanent cells, ground electrodes for grounding T/R unit, anode cables, cathode cable, measurement cables, power cables, etc.

3.09 The type of anode and anode bed for the ICCP System shall be in conformance with BS 7361 Part 1.

3.10 Required number of test stations shall be provided for the ICCP system for system monitoring and testing.
4.0 SCOPE OF WORK

4.01 The broad scope of work shall cover the following for the various systems and equipments mentioned under this clause :-

(i) Complete soil resistivity survey for the pipelines along the entire buried pipe lengths.

(ii) Detailed design as per the design data, standards and codes of practices specified and the approved soil data.

(iii) Carrying out detailed engineering to BHEL approval.

(iv) Complete manufacture including shop fabrication, assembly, and testing and inspection at manufacturer's works.

(v) Sea-worthy packing, forwarding and transportation from the manufacturer's works to the Chennai port.

(vi) Supervision of erection and commissioning, including but not limited to fabrication and/ or pre-assembly, if any, civil works, testing and putting into satisfactory operation of all the equipment/ system and handing over to Owner / BHEL and successful completion of initial operation.

(vii) Conducting Functional Guarantee tests after successful completion of initial operation.

(viii) Providing all the design drawings, design calculations, technical data sheets, “As Built” drawings, manufacture and assembling practices, construction/ installation practices, test procedures followed during manufacturing, erection and commissioning, conducting Performance & Guarantee testing, carrying out monitoring services etc., and submitting Operation & Maintenance manuals for BHEL’s review, approval and records.

4.02 Though actual erection and commissioning are not in vendor’s scope, all erection and commissioning activities shall be carried out at project site under vendor’s supervision. Vendor’s technical personnel of suitable qualification and experience and in sufficient numbers shall be deputed to project site for soil resistivity survey and supervision of complete erection and commissioning till the system is successfully commissioned to the satisfaction of owner / BHEL i.e. acceptance of PG testing of the system.

4.03 Impressed Current System shall typically consist of:

a) Required numbers of anodes in sheet steel canister filled with petroleum coke breeze, back fill materials etc.

b) 1 No. anode junction box per CP Station.

c) 1 No. T/R unit per CP station.

d) Single core, 10 sqmm stranded copper conductor, PVC insulated, overall FRLS PVC sheathed armoured cable required for connection between anode and junction box.

e) Single core of required cross-section stranded copper conductor, PVC insulated, overall FRLS PVC sheathed armoured cable for connection from T/R unit to junction box and pipeline.

f) Two core of required cross-section stranded copper conductor, PVC insulated, overall FRLS PVC sheathed armoured power cable for power connection from power supply source to T/R unit.
g) Required thermit weld cartridges complete with mould and all accessories of cathodic measurement bonding cables with pipeline and welding of the same with the pipeline.

h) Pure epoxy encapsulation of the anodes and cable connections to pipeline.

i) All civil, structural and electrical materials required for installation of CP system.

j) All materials required for laying and termination of cables including cable trays, GI conduits, lugs, glands, markers, grounding material, etc.

k) Required numbers of resistance bonding with test stations at power line crossing/ electrical traction/ rail crossing as and where required.

l) Required zinc grounding cells and Kirk cells.

m) Required insulation joints (depending on no. of pedestals and overhead bridges/ trestles installed to support pipeline) for isolating the cathodically protected piping system from the piping systems/ equipment/ structure/ facilities that are not cathodically protected.

n) Required numbers of permanent reference cells.

o) Complete permanent (for 30 years) protection of casing and carrier pipelines using additional zinc anodes at each encased pipe crossing.

p) Two sets of portable instruments and accessories required to monitor the performance of CP system such as corrosion voltmeters, multimeters, meggar, portable reference cells, electrodes etc.

q) Outdoor type test stations along the pipe routing at intervals not exceeding 1000 meters and at locations of each of the road/ rail/ drain crossings.

Successful bidder shall submit a complete Bill of Materials for the complete system after approval of basic design documentation which shall be to BHEL’s approval.

4.04 Bidders shall submit the list of recommended O&M spares (optional) for trouble free operation for 5 and 10 years for the complete cathodic protection system.

4.05 Successful bidder shall provide monitoring services for the complete CP system and its equipment for one (1) year from the date of completion of guarantee tests.

4.06 All other materials which may be necessary but not mentioned herein specifically to complete the cathodic protection system in all respects to the best engineering practices shall be in the vendor’s scope.

4.07 All materials, consumables, special tools and tackle, testing instruments and machines required for execution of the work are also included in vendor’s scope.

4.08 Vendor shall be responsible for supervision of conduction of all tests required as per specification. The scope includes making all arrangements (including supply of materials) for all tests, overseeing the performance of tests in presence of Owner/ BHEL’s representative. Submission of results for approval and all rectification work, if required.

Vendor shall also be responsible for accurately recording and maintaining records of all tests as per requirement of Owner/ BHEL representative.

4.09 All instruments and consumables required during erection/ pre-commissioning, performance testing and monitoring shall be arranged by the vendor.
4.10 Support pipes/structures for junction boxes etc. shall be part of scope of supply

4.11 All other materials necessary but not mentioned herein specifically to complete the cathodic protection system in all respects to the best engineering practices shall be included by the bidders.

4.12 Terminal points: BHEL shall provide 2 nos. (1 working + 1 standby) 220 V, single phase, 50 Hz AC power supply uncabled feeder modules at LT panels/AC distribution boards located in Fuel Oil PH and CW PH. Bidder to indicate the rating of feeders and power requirement for the same. Cables from the feeder modules/ changeover between feeders/ inter-locks/protection devices/ any other supply etc. shall be in bidder’s scope only.

5.0 BASIC DESIGN DATA/ GUIDELINES

5.01 The data of pipelines to be protected and the wrapping and coating employed for the protected pipelines are indicated elsewhere in the specification. (please refer content sheet)

5.02 The cathodic protection system will be sized in order to guarantee, at each point of same system, the minimum pipe-to-soil potential value of (-) 0.95 V versus Cu/CuSO₄ half cell reference electrode. The maximum negative potential value allowable at the drainage point will be (-)1.2V (as per BS7361/1991 - Section 2, Table 1).

5.03 Overall design Pipeline coating efficiency shall be considered as not more than 70% through out the design pipeline of 30 years for design of ICCP system.

5.04 The design current protection density shall not be less than 0.5 mA/Sqm and 20% design current is to be kept as provision for redundancy.

5.05 The design anode consumption rate shall not be less than 0.4 Kg/Amp/year for High Silicon chromium iron anode.

5.06 Design life for the ICCP system shall be not less than 30 years.

5.07 The rating of transformer rectifier shall be considered for an additional requirement of 25% power compared with the power required under normal operating condition.

5.08 Vendor shall submit detailed design calculations for the design of the entire system after award of contract for BHEL approval.

5.09 As part of corrosion survey full particulars regarding secondary structure including power cables, communication lines, electrical railway tracks etc. which would adversely influence the system or would be influenced by the system must be collected. The cathodic protection system would incorporate suitable mitigation measures for varying types of soil and moisture content.

5.10 Cathodically protected section of the pipe line shall be electrically isolated by use of insulating joints.

5.11 The carriers in the cased crossings with seals shall be protected by zinc sacrificial anodes. The anodes shall be in the form of ribbon or arc shaped rod and would be welded to the carrier pipe by thermit welding as close to the carrier pipe as practically possible. The length of the ribbon anode would be equal to the length of the carrier pipe inside the casing and anodes will be mounted over the circumference in such a way that it is distributed equally at 120° angle between them.

5.12 The external of casings would be coated in the same manner as carrier pipes and also provided with zinc anodes on both sides of the pipe.

5.13 As part of cathodic protection monitoring, potential measuring devices would be installed at all test stations. The test station would also provide the flexibility for connecting and disconnecting sacrificial anodes. Some of the test stations having potential measuring terminals shall also have terminal facilities for measuring line currents.

5.14 TEST STATIONS
(i) Test stations along the pipeline shall be provided along the ROW for monitoring the performance of cathodic protection system and bonding of pipe lines in common pipe trench or ROW at intervals not exceeding 1000 meters. Test stations shall have, besides pipe-to-soil potential measurement and bonding facilities, four terminal facilities for line current measurement.

(ii) In addition measurement station shall also be provided at following locations:

   a) At both sides of major water, road and rail cased crossings.
   b) At all insulating joints. The test station shall have terminal facility for connection of grounding cell to pipeline. Besides terminals shall also be provided for pipe-to-soil potential measurement on both shoulders of joint.
   c) At crossing of AC/DC electric traction system.
   d) At vulnerable location with drastic change in soil resistivity.
   e) At HT overhead line crossings and selected locations where HT line passes close to pipe line.
   f) In vicinity of DC networks or grounding system where interference problem are suspected.
   g) At valve location.
   h) At crossing of other foreign pipe lines (bonding facility with resistor shall be provided).

(iii) Additional test stations described above, many of which shall fall intermediate between potential test-cum-bond stations, shall have binding facilities. Some of these additional test stations meant for a single pipe or such additional test stations may coincide with those test stations located at 1000 metres interval.

(iv) Test stations at location of insulating joints shall be installed independently. Details of terminal facilities and connection schemes for individual type of test station/ current measuring station/ test-cum-bond station shall be as per relevant standards.

(v) The location of all the test stations shall be marked with their connection schemes and other relevant information on alignment sheets as a part of detailed engineering. A test station schedule shall also be prepared.

(vi) Potential test-cum-bond station provided at regular interval as a means to bond, monitor and control current flow in structures laid in common ROW/trench. These potential test-cum-bond station shall allow detection and mitigation of any interference on foreign structures that may result from operation of this CP system.

5.15 REFERENCE ELECTRODES

i) Reference electrodes shall be provided to:

   a) Obtain the most reliable indication of the protection and system behaviour.
   b) Ascertain the effectiveness of each CP station and control their output.

ii) For separate control, reference electrode including one standby should be placed on all the individual pipelines.

iii) High purity copper/ copper sulphate and silver/ silver chloride reference electrodes shall be used to provide stable potential measurement references.
iv) For each automatically controlled cathodic protection system, monitoring reference electrodes shall be supervised by a duplicate electrode in its close vicinity in an approved location.

v) Such duplicate electrodes shall be provided to guard against reference cell failure possibilities in an unattended automatic system. Facilities shall be provided to reject spurious signal during open or short circuiting of monitoring point.

vi) Vendor shall provide 30% spare reference electrode complete with accessories. Number and type of electrodes to be supplied by vendor shall be approved by BHEL.

6.0 SYSTEM DESIGN AND PERFORMANCE CRITERIA

6.01 Standards and Code of Practice

The design, manufacture, shop testing, erection, fabrication at site testing and Initial operation of the cathodic protection system shall conform to the latest revision of following standards and code of practice as specified herein after.

1) BS 7361 Part 1 [Cathodic Protection Code Practice for Land and Marine Application]

2) NACE (USA) Standard RP-0169-02 [Recommended Practice for Control External Corrosion on Underground or submerged metallic piping system].


4) Ferrous Pipeline Corrosion Process Detection & Mitigation

5) Latest international practices, acts and regulations.

The responsibility of establishing conformance to above shall lie with the vendor.

6.02 Performance Criteria for Cathodic Protection

While monitoring effectiveness of cathodic protection, the following criteria shall be applied in principle to achieve a reliable and an easy check of its effectiveness:

i) (-)0.85 V pipe-to-soil potential (P-S-P) with respect to Copper-Copper Sulphate half cell (reference) electrode in absence of an anaerobic bacteria and (-)0.95 V pipe-to-soil potential with respect to Copper-Copper Sulphate half cell (reference) electrode in presence of an aerobic bacteria (both with the Cathodic Protection System switched ‘on’).

ii) A minimum negative (cathodic) voltage shift of 300 mV produced by the application of protective current. The voltage shift is measured between the structure surface and a stable reference electrode contacting the electrolyte.

iii) A minimum negative (cathodic) polarization voltage shift of 100 mV measured between the structure surface and stable reference electrode contacting the electrolyte. This polarization voltage shift is to be determined by interrupting the protective current and measuring the polarization decay. When the current is initially interrupted, an immediate voltage shift will occur. The voltage reading after the immediate shift shall be used as the base reading from which to measure polarization decay.

iv) A net protective current flow from the electrolyte into the structure surface as measured by an earth current technique applied to predetermined current discharge (anodic) points of the structure.

7.0 FUNCTIONAL GUARANTEE
7.1 The vendor shall give functional guarantee as elaborated below:

a) The vendor shall guarantee that the performance/function of the CP system installed shall be strictly in accordance with and conforming to the codes specified and shall perform the specified duties as per the performance criteria specified in CI 6.02.00 of this Section.

b) If the vendor fails to prove the functional guarantee of the CP system set forth in the tender documents, the vendor shall investigate the causes and provide free of cost to BHEL, services of vendor’s Project Engineer to rectify/replace the defects within a reasonable period to prove the guarantees. Vendor’s liabilities in this respect shall be unlimited.

c) If the vendor fails to prove the guarantee within a reasonable period, BHEL shall have the option to take over the equipment and rectify the same to fulfill the guarantee and/or to make necessary additions to make up the deficiency at the Vendor’s risk and cost. All expenditure incurred by BHEL in this regard shall be to vendor’s account.

d) Functional guarantees shall be in respect of the entire cathodic protection system including material supplied and utilized in the CP system.

e) The functional guarantees for Cathodic Protection system after allowing for applicable tolerances as per codes shall be demonstrated by the vendor to BHEL.

f) On successful completion of initial operation, the systems and equipments shall be subjected to functional guarantee test and parameters shall be verified during the test.

g) After successful conductance of the guarantee tests, the monitoring services of the system shall be carried out by the vendor and the system parameters shall be maintained.

8.0 INSPECTION & TESTS

8.1 The vendor shall arrange inspection of the following material before their use at site:

a) All items procured by the vendor whether indigenous or imported.

b) Shop fabricated items at vendor’s workshop.

c) Erection work at site (stage wise) including testing of complete Cathodic Protection System.

8.2 Owner/ BHEL or their authorized representative reserves the right to visit vendor’s, vendor’s sub-vendor’s shops for the inspection/quality assurance control & expediting and to be present at the time when the vendor’s inspection is being carried out. Such inspection by the Owner/BHEL however in no way relieves the vendor of his responsibilities & obligations.

8.3 The Vendor is responsible for carrying out all tests and checks envisaged in compliance with specifications & to request the Owner/BHEL’s inspector to be present when required so as to meet the provisions of the contract. All expenditure in respect of testing of materials shall be borne by the Vendor unless otherwise specified.

8.4 All inspection & tests shall be according to the method indicated in the specifications/codes/construction drawings.

8.5 The entire erection of the CP system shall be finally inspected by the Owner/BHEL to check its conformity with all the drawings & specifications furnished. The vendor shall rectify all the defects and finally hand over the system to the entire satisfaction of Owner/BHEL.

9.0 SYSTEM TESTING/ COMMISSIONING
Vendor shall furnish the detailed field testing and commissioning procedure for BHEL approval. Field tests as per approved procedures shall be carried out on the equipment/ systems being put into service. Field testing and commissioning shall generally include but not be limited to the following:

9.1 **System Testing**

a) Vendor shall supervise pre-commissioning operations after installation of the system including pre-commissioning checks, calibration and setting of all instruments, control and protective devices. All site tests, reliability and performance tests shall be carried out including supply of all materials and consumables. Before the electrical facilities are placed in operation, vendor shall supervise suitable tests to establish to the satisfaction of the Project Engineer in-charge that all equipment, devices wiring and connections have been correctly installed and are in good working conditions.

b) All the test results shall be filled in the proforma to be developed by the vendor and subsequently approved by the Project Engineer-in-charge. The proforma shall be jointly signed by the Project Engineer-in-charge and vendor.

c) Generally the following tests shall be carried out and recorded on the proforma given in subsequent clauses.

<table>
<thead>
<tr>
<th>Checking</th>
<th>Visual inspection, comparison with drawings and specifications.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection</td>
<td>Detailed physical inspection and if necessary, by taking stage wise inspection of component parts.</td>
</tr>
<tr>
<td>Testing</td>
<td>Simultaneous tests and trial runs of entire equipment to determine its operational fitness.</td>
</tr>
</tbody>
</table>

9.02 **Proforma for testing**

<table>
<thead>
<tr>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Transformer Rectifier Unit</td>
</tr>
<tr>
<td>- Location/ Station</td>
</tr>
<tr>
<td>- Type, Size &amp; Sl. No.</td>
</tr>
<tr>
<td>- Rating</td>
</tr>
<tr>
<td>- Insulation resistance primary to earth, secondary to earth, primary to secondary</td>
</tr>
<tr>
<td>- Polarity check</td>
</tr>
<tr>
<td>- Testing of oil (if any)</td>
</tr>
<tr>
<td>- Check neutral connection</td>
</tr>
<tr>
<td>- Equipment Earthing</td>
</tr>
<tr>
<td>- Operation of tap changer</td>
</tr>
<tr>
<td>- Rectifier continuity &amp; diodes polarity.</td>
</tr>
</tbody>
</table>

b) Cables

| Cable No. |
- Voltage grade
- Conductor cross section
- Continuity check
- DC test voltage
- Insulation resistance values
  
  Between each core & earth and
  
  Between each core & other

All control cables shall be tested by 500 V megger and all LT power cables shall be tested by a 1000 V megger.

c) Panel

- Location
- Assembly Inspection
- Checking of wiring as per schematics
- Inspection of safety features and their functioning
- Testing anti condensation heaters
- Check circuit numbering
- Insulation resistances of different independent circuits
- Panel to panel connection
- Checking of external cable connections
- Checking of indicating measures and recording circuits
- To carryout simulation test

d) Insulating flanges/joints

- Checking of insulation resistance across the joint before and after charging the line
  
  by means of insulating-flanges/joint tester.

e) Earthing network

- Location / Station
- Number of electrodes
- Type of electrodes
- Earthing resistance of each electrode
- Earthing resistance of earthing net work
f) Anode-Ground Beds  
- Location / Station  
- Check for its actual & its comparison with drawings  
- Resistance of each individual anode  
- Current dissipation by each individual anode at different likely voltage  
- Total resistance of complete anode bed.  
- Mutual interference  

9.03 Commissioning Procedure  
The installed cathodic protection system shall be commissioned as per following general procedure and the same shall be modified as per the system design parameters.  

a) On completion of installation of cathodic protection stations, anode-beds and modification/integration of corrosion monitoring system as envisaged in this specification, all the elements of the system shall be individually checked, tested and compared against the agreed specifications and procedures. Subsequently the parameters of the anode-beds shall be checked for their veracity. Total anode-bed resistances shall not exceed the calculated design figures.  
b) Current dissipating capacity of each anode bed shall be measured and checked.  
c) Electrical continuity of the entire pipeline shall be verified in conformity with design and terminal resistances shall not be allowed to be less than anticipated across the insulating joints.  
d) All the insulating joints shall be individually checked for intended electrical isolation.  
e) Input resistances of the pipeline at the drainage points shall be checked and recorded.  
f) Overall circuit resistance of individual installation shall be measured and recorded.  
g) Grounding and polarization cells shall be checked for their expected performance.  
h) If any temporary protection facilities are provided, the same shall be disconnected from the system.  
i) Bonding between individual pipes in common ROW/pipe trench shall be ensured.  
j) Protection to all lines installed in existing CP Stations shall be switched off and the lines be depolarised for minimum 48 hours.  
k) Before the pipelines are put on charge by switching on any of the CP Stations, natural pipe-to-soil potential values shall be measured with respect to Cu/CuSO₄ half cell.  
l) For each CP system, one of the T/R unit at one CP station end shall be energized to an output regulated manually so as to achieve a maximum structure-to-electrolyte potential of w.r.t. Cu/CuSO₄, half cell nearest to drainage points of each line. Observations of spread of
protection of each line under this system shall be taken for structure to electrotypic potential at each of the installed test station till a value of (-)0.95 volts w.r.t to CU/CuSO₄ is reached. Also the pipe line current values across the cross section of the pipeline shall be determined at all the intended test stations influenced by this station. Operating parameters of the T/R unit shall also be recorded.

m) Thereafter the T/R unit at the other CP station end shall be energized after switching off the CP station which was tested. The same procedure as (l) shall be adopted and PSP values recorded. This T/R station shall then be switched off. After ensuring that both T/R units are in order, both shall be switched on simultaneously and PSP values shall be recorded along the entire pipelines at each test station.

Sufficient time must be allowed to elapse between switching on the CP station and recording of pipe to soil potential values.

n) Three complete sets of observation shall be recorded every 24 hours interval of line having stayed on charge after the completion of Sl. No. (m).

It is to be ensured that there is no appreciable difference in the observations and in case of any variations in potentials, the procedure shall be repeated. All the commissioning records shall be recorded in a prescribed proforma and analysed.

o) During the commissioning, maximum protective potential should not be permitted to exceed the design value.

p) Next, the output of the CP station shall be so adjusted that the sites of occurrence of minimum protective potentials are brought down to (-)1.00 V for portion. A full set of observations shall again be taken 72 hours after the first set and the protective systems shall be left in this state or operation.

q) Care shall be exercised that power supplied remains uninterrupted during the period of commissioning, otherwise, in case of an interruption, the test in progress shall be repeated. More sets of observations may be advised to be taken by the Project Engineer in any of the above mentioned steps.

r) After proper polarization (minimum 72 hours), the CP system shall be switched off and the immediate momentary pipe to soil potential measured. This gives the OFF potential which should match with the design value at any point of the pipeline.

s) PSP potentials at all the insulation joints shall be checked before and after energisation of the CP station and shall be recorded.

t) A Pearson survey/ CPL shall finally be run over the entire length of pipeline to detect any holes in the coating which may have developed during backfilling. Coating repairs if any shall be carried out by the vendor. Vendor shall submit a procedure for running this survey for Project Engineer’s approval. This step may have to be performed as soon as back filling and compaction is completed.

u) Finished records of testing & commissioning shall be completed with interpretation and submitted for approval.

v) As a result of these tests, if any deficiencies are found in the system, the same shall be rectified by the vendor to the satisfaction of Project Engineer. Such deficiencies shall include mitigation of interaction problems that may be found existing in the course of testing and commissioning. This shall also include a set of SEP observations taken during the peak of first dry season in the area after commissioning the system into regular operation.

w) While commissioning if it is found that the sites of occurrence of minimum protective potentials are below design value for marshy land portion even after 72 hours, the maximum protective drainage point potentials shall be increased depending on Anode Ground Bed
current in consultation with Project Engineer. In any case, rectified potential value and the Off Potential of the CP system shall not exceed the design value w.r.t. Cu/CuSO₄ cell. The upper limit of pre-set reference SEP value at transformer rectifier unit at which it should operate at permanent half cell failure should then be adjusted according to rectified maximum protective potential value.

x) Vendor shall arrange during commissioning, a cable less potential sensing or any other suitable means proved viable to measure structure-to-electrolyte potentials without requiring physical contact with the monitored structure for the offshore portion only.

10.0 DOCUMENTATION

10.01 Technical offer along with bid

Two signed and stamped copies of the following shall be furnished by the bidder as compliance to the specification:

a) Unpriced Price Schedule (As enclosed with the specification) with bidder’s signature and company stamp.

b) A copy of the sheet (“Instructions to Bidders for Preparing Technical Offer”) and previous sheet (“Contents”), with bidder’s signature and company stamp.

10.02 The technical offer shall also include the following as a minimum requirement:

a) Complete technical write-up of system including brief details of major equipments
b) Typical schemes / drawings
c) Catalogues/ leaflets
d) List of orders successfully executed/ under execution
e) Performance feedback for completed orders

10.03 The following minimum design documentation [not essentially limited to these only] shall be furnished by the successful vendor (for review and approval) at contract stage.

2. Basic design package and system optimisation studies.
3. Material and equipment specifications, data sheets.
4. Quality plans for all equipment/ items.
5. Field Quality Plan covering site storage, handling, installation and commissioning checks.
6. Detail engineering and final design report.
7. Key diagrams of each discrete systems and complete CP system.
8. Anode installation drawings representing all variations in type, environment, depth, placement, supports etc. including anode.
9. Cable layout schedules and terminals.
10. Foundation, weather protection cover details and support details for T/R sets, anodes, Test Station, distribution boxes and cables of all description.
11. Installation details of T/R sets, test stations distribution boxes etc.
12. Design package on T/R sets essentially incorporating circuit diagrams, fabrications and installation details, parts list, description on operation and maintenance.
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>14.</td>
<td>Connection schemes for all applicable type of test stations and their schedules.</td>
</tr>
<tr>
<td>15.</td>
<td>Fabrication and installation details of test stations.</td>
</tr>
<tr>
<td>16.</td>
<td>Fabrication and installation details of anode and cathode junction boxes, schedules and connection schemes.</td>
</tr>
<tr>
<td>17.</td>
<td>Interconnection, sectionalisation, isolation schemes for all structures to be protected and those to be isolated but to be checked out for interaction.</td>
</tr>
<tr>
<td>18.</td>
<td>Power supply arrangement for each T/R set.</td>
</tr>
<tr>
<td>20.</td>
<td>Procedures for testing during installation, commissioning and monitoring of (after installation) complete CP system &amp; each equipment.</td>
</tr>
<tr>
<td>21.</td>
<td>Design and drawings that may be required for mitigation purposes.</td>
</tr>
<tr>
<td>22.</td>
<td>Complete CP system layout drawings for each CP station.</td>
</tr>
<tr>
<td>23.</td>
<td>Cable to pipe joint arrangement using thermite welding.</td>
</tr>
<tr>
<td>24.</td>
<td>Material test certificate for the materials purchased by the vendor along with copy of manuals.</td>
</tr>
<tr>
<td>25.</td>
<td>Inspection and test certificates for items fabricated and erected.</td>
</tr>
<tr>
<td>27.</td>
<td>Final check list and completion report.</td>
</tr>
<tr>
<td>29.</td>
<td>Monitoring formats.</td>
</tr>
<tr>
<td>30.</td>
<td>Monitoring schedules.</td>
</tr>
<tr>
<td>31.</td>
<td>List of E&amp;C Spares.</td>
</tr>
<tr>
<td>32.</td>
<td>Billing break-up</td>
</tr>
</tbody>
</table>

Note: The list of deliverables shall be finalised during kick-off meeting at contract stage.
ANNEXURE-I

TECHNICAL REQUIREMENTS

FOR

ANODES AND BACKFILL
1.0 Anode and backfill material and construction shall be in accordance with the standards listed in the specification, and shall be in proven use.

1.01 Each anode shall be provided with heat shrunk anode caps matching the anode size. These caps shall be moulded out of radiation cross-linked PE material which shall be heat shrinkable and the material characteristics shall be furnished by the vendor for approval of the BHEL.

1.02 Each anode shall be installed at least 30 meters away from the pipeline and at a depth of 1.0 to 1.2 meter from the level of pipeline. The exact location shall be identifiable by means of suitable marker on the ground to be supplied by vendor. The spacing between two consecutive anodes shall be one (1) meter.

1.03 Each anode shall be installed inside a pipe canister of suitable diameter, length and thickness, so that the backfill is properly consolidated. Two centralizers shall be provided to aid centring of the anode inside the canister. Proper compaction shall be done while pouring backfill material inside the canister. The pipe shall be driven underground after auguring of the hole of required dimensions.

1.04 Anode-bed plot limited up to ROW shall be surveyed for topographic details, its location and orientation shall be reviewed by Project Engineer. A complete drawing showing plots, sub-plots, center line of sub plots, resistivity readings, connection to CP station and to pipeline structure, cable trench layout, etc., shall be submitted along with supporting reasons for anodes bed site selection to Project Engineer on the basis of corrosion survey report prepared by vendor.

1.05 Layout of anodes and installation in anode-bed shall be detailed out in a separate drawing showing anode installation details, anode grouping, anode wiring etc. Type of layout whether vertical installation, horizontal installation in shallow depth to be considered shall be decided in consultation with Project Engineer on the basis of corrosion survey report prepared by vendor.

1.06 Necessary connection of anode lead cable in anodes, packing of anodes in canisters filled with backfill, soldering or canisters shall be supervised at site.

1.07 Each anode shall have lead cables of sufficient length to reach anode junction box without joints in between. Exact length and termination details shall be shown in construction drawings.

1.08 Anode bed separation from pipeline shall be tested for interaction.

1.09 At landfall points, anode landbeds may be laid, if situation demands, between low and high water line or very near low water line. The configuration shall be horizontal in such cases.

1.10 Sizing of ground bed at each CP station shall be such that its total resistance to remote earth does not exceed 0.5 Ohm inclusive of anode lead cable resistance. Potential gradient around the anode bed shall be within safety requirements and its effective boundary shall be defined and secured.

1.11 The boundary of the anode bed should be clearly marked with the help of permanent boundary of fencing.

1.12 Cables:

i) Anode tail cable shall be single core 10 sqmm stranded tinned copper conductor, PVC insulated, FRLS PVC sheathed and armoured type. Anode cable tail shall be long enough to reach the junction box without intervening joint. The cable shall be routed inside a GI pipe conduit. Each cable routing shall be marked clearly with markers supplied by vendor.

ii) The mechanical strength of the anode/ anode cable joint shall be such that weight of the freely suspended anode can be supported.
iii) The connector to be used for anode lead connections shall be zinc alloy. The installed connector shall have a minimum pull-out strength of 200kg and a total electrical contact resistance not exceeding 0.0090 ohms as measured across both the copper-to-connector junction and the connector-to-anode junction.

iv) The connection shall be insulated by completely filling the hole with an approved cold applied polyurethane insulating compound at al least 12 inches on both above and below connector.

v) Filling with insulating compound shall be carefully accomplished to ensure a waterproof connection.

2.0 INSPECTION & TESTING

2.01 The vendor shall furnish spectrographic analysis of anodes from each heat.

2.02 Inspection and Testing shall be carried out on the anodes and the backfill material to demonstrate that the material is conforming to the physical, chemical and others parameters specified and test certificate shall be submitted to the Owner / BHEL for approval.

2.03 The vendor shall submit a certified test report from anode manufacturer showing that the connecting method has passed a 120 day laboratory test without failure at the place of connection when the anode is subjected to its maximum recommended current output continuously while immersed in a 3% weight sodium chloride solution.

2.04 All anodes shall be subject to inspection by BHEL or BHEL representatives. Any anode having a surface defect with penetration in excess of 5 mm shall be rejected.

2.05 The box shall be split into sections to enable the cable tails to be packed at one end in their separate compartment. All free space shall be tightly packed with soft packing material.

2.06 In the event of damage or breakage occurring as a result of inadequate packing, the vendor shall replace the same at no additional cost of BHEL.
ANNEXURE II

TECHNICAL REQUIREMENTS

FOR

CABLES, CABLE LAYING AND TERMINATION
1.0 SCOPE

This specification covers the technical requirements for all cables viz. Anode cables, cathode cables, anode tail cables, potential measuring cables, current measuring cables, cables for bonding, cables for earthing, cables for permanent half cell connections, power supply cable etc. The specification for cable laying are detailed hereunder.

2.0 Cables shall be 1.1 kV grade with stranded copper conductor, PVC Type-A insulation, core identification by colour coding, distinct extruded inner sheath of PVC type ST1 material, aluminium round wire armour for single core cables and GS round wire/strip armour for multi-core cables, and extruded PVC Type ST1 outer sheath with FRLS properties, generally conforming to IEC-60502 (Part-1).

3.0 SIZE AND CORE OF CABLE

The size of various types of cables stated above are listed below:

<table>
<thead>
<tr>
<th>Cable Type</th>
<th>Core</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anode Cables (T/R unit to JB)</td>
<td>1-C</td>
<td>As per requirement</td>
</tr>
<tr>
<td>Cathode Cables (T/R unit to pipeline)</td>
<td>1-C</td>
<td>As per requirement</td>
</tr>
<tr>
<td>Anode Tail Cables</td>
<td>1-C</td>
<td>10 mm</td>
</tr>
<tr>
<td>Potential Measurement</td>
<td>1-C</td>
<td>10 mm</td>
</tr>
<tr>
<td>Current Measurement</td>
<td>1-C</td>
<td>10 mm</td>
</tr>
<tr>
<td>Bonding</td>
<td>1-C</td>
<td>25 mm</td>
</tr>
<tr>
<td>Grounding</td>
<td>1-C</td>
<td>25 mm</td>
</tr>
<tr>
<td>Half-cell connection Cable</td>
<td>1-C</td>
<td>10 mm</td>
</tr>
<tr>
<td>Earthing cable</td>
<td>1-C</td>
<td>35 mm</td>
</tr>
<tr>
<td>Power Cable</td>
<td>2-C</td>
<td>As per requirement</td>
</tr>
</tbody>
</table>

4.0 CABLE TERMINATION

4.01 The cables shall be taken through double compression glands inside all equipment/panels.

4.02 Termination of cables shall be done with crimped heavy duty copper lugs supplied along with the equipment with proper crimping tools.

4.03 Control cables of single strand shall be directly terminated on to the terminals. An aluminium tag/PVC ferrule for identification of the cable shall be attached to each cable at both ends. Power cables shall be identified with red, black and blue PVC adhesive tapes/sleeves.

5.0 CABLE IDENTIFICATION

5.01 All cables will be identified and labelled at terminal blocks of test station and transformer rectifier.

5.02 To this purpose, coloured heat shrinkable sleeves will be supplied for use as per following colour code key:

<table>
<thead>
<tr>
<th>Identification</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure to protect</td>
<td>Green</td>
</tr>
<tr>
<td>Structure to T/R U connection</td>
<td>Green</td>
</tr>
<tr>
<td>Groundbed to T/R U</td>
<td>Red</td>
</tr>
<tr>
<td>----------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Casting Pipe</td>
<td>Blue</td>
</tr>
<tr>
<td>Plant side shorting connection</td>
<td>Green/Brown</td>
</tr>
<tr>
<td>Monitoring connection</td>
<td>Black : White</td>
</tr>
<tr>
<td>Reference cell</td>
<td></td>
</tr>
<tr>
<td>Half cell</td>
<td>Yellow</td>
</tr>
<tr>
<td>Structure</td>
<td>Yellow/Green</td>
</tr>
</tbody>
</table>
ANNEXURE III

TECHNICAL REQUIREMENTS

FOR

JUNCTION BOX
1.0 SCOPE

1.01 This specification covers the technical requirements for Junction Boxes [JB] to be used for anodes (cable termination).

2.0 DESCRIPTION

2.01 Installation of junction boxes shall depend upon site conditions. JBs to be mounted above ground shall have steel enclosures which shall be weather proof IP-65 class with hinged lockable shutters. JBs shall have terminal bakelite block with adequate/ appropriate brass Elmex type terminals as per prior approval of BHEL. It shall be suitable for cable gland entries for incoming and out coming cables. Atleast 30% spare terminals shall be provided.

2.02 The JBs shall be fabricated from cold rolled steel of minimum thickness 3.0 mm, suitable painted. They shall be suitable for use in a highly corrosive environment. Suitable canopy shall be provided for protection against rain.

2.03 JBs shall have a removable gland plate at the base. A hinged detachable front facing lid shall be provided with a minimum of one locking point. A suitable lock shall be provided along with two (2) sets of keys. The box shall be weather proof and sealed against the ingress of dust and moisture, conforming to IP-65. Both the gland plate and the lid shall be provided with sealing gaskets.

2.04 The box shall be provided with a rain mounted termination panel affixed to internal standoff tapered pillars, allowing adequate clearance behind the termination panel.
ANNEXURE IV

TECHNICAL REQUIREMENTS

FOR

REFERENCE ELECTRODES & GROUNDING CELLS
1.01 This specification covers technical requirements for reference electrodes to measure structure-to-electrolyte (P-S-P) potential in cathodic protection systems. Reference electrodes are to be used for measuring structure/electrolyte potentials, or as sensing electrodes for control systems.

1.02 A copper/copper sulphate reference electrode is to be used for making contact with soil and fresh water while a silver/silver chloride reference electrode is preferable for immersion in saline waters. Zinc electrodes can be used in clean sea water. Electrodes to be used as sensing electrodes shall be so designed as to be stable over a long period (minimum 10 years).

1.03 In reference electrodes having a metal electrode in contact with a concentrated salt solution (e.g. copper sulphate or potassium chloride), concentration is maintained by excess solid salt being present. Contact with the electrolyte (i.e. soil or water) is made via a porous plug of ceramic construction acting as salt bridge between the electrolyte and the concentrated salt solution. These electrodes will remain suitable for use until the salt is exhausted by diffusion through porous plug. When not in use, these should be stored in a saturated solution of the relevant salt.

1.04 Testing of reference electrodes as per standards shall be witnessed by BHEL before despatch.

1.05 **COPPER/ COPPER SULPHATE REFERENCE ELECTRODE**

1.05.1 A form of copper/copper sulphate reference electrode that is suitable for measurements under most conditions, including probing, shall be supplied by the bidder. The dimensions may be made to suit the method of use, but the surface area of copper electrode in contact with the copper sulphate solution should be large enough to prevent polarization during test. The metallic electrode should be of high conductivity copper of at least the purity specified for grade C101 in BS 2874.

1.05.2 The copper should be cleaned to remove all traces of oxide and grease and immersed in saturated copper sulphate solution. Saturation shall be maintained by providing excess solid copper sulphate. The copper sulphate solution shall be made with fine crystals of copper sulphate to at least analytical reagent (AR) grade or British Pharmacopoeia (BP) quality with distilled or de-ionized water which shall be boiled in a clean glass or enamelled container before use. Electrical contact with the soil is made only through the porous element, which is kept moist by seepage of copper sulphate solution. Electrodes shall be immersed in saturated copper sulphate solution for long duration storage.

1.06 **SILVER/ SILVER CHLORIDE REFERENCE ELECTRODES**

A silver/silver chloride electrode is formed from silver, the surface of which has been coated with silver chloride by thermal or electrolyte methods. The silver/silver chloride element shall be used directly in sea water or saline estuarine waters. In other applications (e.g. steel in concrete) a silver/silver chloride/potassium chloride electrode may be used.

Electrodes for use in sea water shall be encased in perforated containers for mechanical protection and to allow free access of sea water to the electrode. They should be immersed in fresh sea water for several hours before use. Cable end shall be insulated to prevent short-circuiting of electrode.

1.07 **INSULATING JOINT (I.J.) GROUNDING CELL**

Grounding cell across each insulating joint shall be provided while its connection to pipe on both shoulders of joint shall be through test station. Besides the above, measurement cable from pipe from shoulders of I.J shall be taken out and terminated in test box.

Grounding cell for each I.J. shall consist of a pair of zinc rods of suitable dimensions. The pair shall be separated by insulation spacers and the entire assembly wrapped with PVC tapes shall be packed in chemical backfill of bentonite, gypsum and sodium sulphate.

1.08 **PERMANENT REFERENCE ELECTRODES**
Minimum two (2) permanent reference electrodes will be required at each drain point one at either side of pipe for each transformer rectifier unit. These reference electrode shall have a stability of plus/minus 5 millivolts at a maximum load of 3.0 micro amps and have a design life of 25 years.

ANNEXURE V

TECHNICAL REQUIREMENTS

FOR

TEST LEAD POINT (TLP)
1.01 This specification covers the technical requirements of Test Lead Point (TLP) to be used to monitor pipe-to-soil potential (P-S-P) level in the underground/buried metal structures.

1.02 The main purpose of TLP is the measurement of (P-S-P). Other than (P-S-P) some of these TLPs will have in-built facility for line current measurement also bonding at pipe crossings protection of casing pipe (if any) and connecting surge diverter (at I/F, if any).

1.03 In order to verify the protection of the pipeline along its route bidder shall install the following test lead points:

- Equipotential test points (E.T.P.) where interference with other buried steel structure will be carried out.

- Shorting insulating joints (S.I.J) at each insulating joint.

1.04 Installation of TLP shall depend on site conditions as per prior approval of BHEL to be mounted above ground with steel enclosures which shall be weather proof IP: 65 with hinged lockable shutters. It shall have a bakelite terminal block with adequate number of anti-locking brass nut bolts for measurement purposes. The cable connection from (underground) pipe has to terminate in one of these TLPs. It shall be suitable for cable gland entries for incoming and outgoing cables.

1.05 Construction from cold rolled steel of 3mm (min) thickness is recommended. The frame must be set in a concrete foundation sufficient to provide sturdy support.

1.06 Name plate shall be provided inside each TLP giving following information: TLP No., connection scheme diagram, location details etc.

2.0 BOX TYPE TLP

2.01 The box shall be of high gland 316 type stainless steel. It shall be suitable for use in highly corrosive environment.

2.02 The box shall have a removable gland plate at its base. A hinged detachable front facing shall be provided with a minimum of one locking point. A suitable lock shall be provided along with two (2) sets of keys. The box shall be weather proof IP 65 and sealed against the ingress of dust and moisture, exceeding the requirements of British standard 5490: 1970. Both the gland plate and the lid shall be provided with scaling gaskets. Cork gaskets are not acceptable.

2.03 The box shall be provided with a rail mounted termination panel affixed to internal standoff tapered pillars, allowing adequate clearance behind the termination panel.

2.04 On completion of all welding, drilling and other fabrication operations, boxes shall be provided with a coat of primer and two coats of epoxy painting of suitable shade both internally and externally.

2.05 Details of the nominal dimensions of the box along with proposed interior mounting and fitting shall be to approval of BHEL.

2.06 The boxes shall be frame mounted such that their horizontal centreline is approximately 1.5m above grade. Details of the proposed frame shall be to BHEL approval. Each zinc rod shall have copper cable of minimum 3m length to reach test station.

The entire grounding cell consisting of zinc rod surrounded by backfill with an overall dimension of 515X515X1500 mm shall be laid underground at a minimum depth equal to pipe burial depth and adjacent to pipe.
2.07 Each box type TLP box shall be labelled individually. The labels shall be engraved to give white letters on a black background and shall be securely attached to the door. Approximate dimensions shall be 50 mm by 150 mm.

3.0 CLEAT TYPE

3.01 A carbon steel cleat plate of 3” X 3” or as approved by BHEL is to be welded below the first above ground flange wherever pipes emerge overground. At the centre of this cleat plate in a predrilled hole, brass nut head is to be fixed to serve as measurement point.

3.02 A carbon steel nut to be welded from the nut head side, below the first overground flange, whenever the pipes emerge overground to serve as measurement point.
ANNEXURE VI

TECHNICAL REQUIREMENTS

FOR

TRANSFORMER RECTIFIERS
1.0 SCOPE

1.01 This specification covers the manufacture, testing and inspection of transformer-rectifiers for Cathodic Protection System.

1.02 The transformer rectifier units shall be a standard product of a manufacturer regularly engaged in production of Cathodic Protection power supplies. The units shall be supplied in accordance with the following specifications and data sheets.

2.0 APPLICABLE STANDARDS

Transformer rectifiers shall meet the requirements of IEC (International Electrotechnical Commission) Recommendations.

- IEC 76: Power Transformer.
- IEC 404-2: Methods of measuring magnetic and electrical properties of magnetic sheet and strip for transformers.
- IEC 287: Calculation of the continuous current rating of cables.
- IEC 144: Degree of protection of enclosures for low voltage switchgear and control gear.
- IEC 146: Semiconductors converters.
- IEC 296: Insulating oils for transformers and switchgear.

When no IEC standard exists, the standards of country of origin shall be used but the bidder must state this in his offer and be prepared to submit copies of said standards in English Language.

3.0 DC OUTPUT ADJUSTMENTS

3.01 The DC output control shall be capable of operating in any of the following modes, with the help of a selector switch:

- **Manual Mode:** Output voltage control at 2 volt steps from 0-50 V shall be available by means of coarse and fine tap changing switches.

- **Auto Mode:** A constant current control will be provided to set the output current to any value up to the rectifier rating. The output current shall not vary more than 1% while the output voltage may vary from zero to 100% depending upon the setting of the voltage control potentiometer. In the constant current mode, the voltage control potentiometer may be used to set the output voltage limit to a desired value.

4.0 Reference Cell Selector Circuit and Control

A circuit shall be used which will accept three (3) reference cell inputs. This circuit will automatically accept the reference with the lowest potential above a pre-selected value higher than the native potential of steel. This limit will minimize the possibility of a rectifier utilising an erroneous reference electrode signal, which could cause over protection to the pipeline. Switches shall be provided to measure the potential of each reference cell used and to allow manual selection of the reference cell to be used.

5.0 Separate-Drainage Control

Provision shall exist to individually drain each protected structure and have both auto and manual mode available on each drain.
6.0 DC OUTPUT RIPPLE

6.01 The single-phase rectifiers shall have an output ripple not exceeding 5%.

7.0 INPUT OVER LOAD PROTECTION

7.01 Protection from over loads on the input will be provided by moulded case magnetic circuit breakers on the input side. These circuit breakers will hold at 100% of rated load. They may trip between 101% and 125% of the rated load and must trip at 125% and above.

7.02 Circuit breakers will be the manually reset type. The trip point will be unaffected by ambient temperature.

7.03 Trip handles of individual pole circuit breakers will be mechanically linked to open all lines when an overload occurs. HRC fuse of suitable rating shall be provided as back up to input circuit breaker.

8.0 OUTPUT OVER LOAD PROTECTION

8.01 Protection from over loads on the output will be provided by an electronic current limiting feature.

8.02 Protection from overload on the output will be set by current limit switches marked “Coarse”, “Fine”. The coarse switch shall give limit of 0, 15A, 30A, 45A, 60A, 75A, whereas the fine switch shall give limit of 0, 3A, 6A, 9A, 12A, 15A.

8.03 The limit of the two switches shall be algebraically additive and shall give 25 steps of 3A each.

8.04 The maximum current limit can be set by operator at any desired value in 3 steps and in any circumstances even in case of short circuit the output current should not exceed the maximum set current limit.

8.05 In addition to above current limiting feature MCCB of suitable rating to be used at positive and negative terminals to disconnect T/R unit quickly in case of over loads in the output circuit.

9.0 VOLTAGE SURGE PROTECTION

9.01 Each silicon-controlled rectifier (SCR) shall be protected from voltage surges by means of R-C circuitry. These devices will be rated such that they will conduct heavily before the peak inverse voltage rating of the SCR’s is exceeded.

9.02 In addition, lightning arrestors shall be provided in the AC input and DC output circuit of the rectifier.

10.0 COOLING

The rectifiers will be natural air-cooled capable of operating simultaneously at rated output in ambient temperature of 45 °C. The effect of direct sunlight is also to be taken into account.

11.0 INPUT AND OUTPUT TERMINALS

11.01 DC terminals shall be located convenient to the cable entrance and shall be solder less pressure type terminals of tin plated copper. Output terminals shall be suitable for 50 sqmm cable cross section. Two negative and one positive output terminals shall be provided.

11.02 AC terminals shall be insulated to withstand 2000 volts 50Hz to the enclosure shall be shielded to prevent accidental contact and shall be sized to take cable sizes of 25mm².

12.0 METERS
12.01 The transformer rectifier units shall be equipped with a separate continuous reading voltmeter and ammeter for DC output and for AC input voltage and current. These meters shall have a full-scale capacity at least 10% above the output rating of the unit.

12.02 The transformer rectifier units shall also be supplied with a 0 to ±2.5 volt corrosion voltmeter with 10 mega-ohm input impedance. This meter shall be connected to a two-way on and off selector switch to allow structure to electrolyte potential measurements to be taken with respect to either of two reference electrodes. This meter is not intended to control the output of the transformer rectifier.

12.03 All meters shall be electronic digital type with LED display arrangement and should be able to indicate the current and voltage ranges as per datasheet unto three decimals. Digit size should be 15mm * 10mm (minimum). Meters shall be rectangular in shape and accurate to within 2% of full scale at 55°C. They shall be temperature compensated to vary no more than 1% per 10°C temperature change.

12.04 All ammeters and voltmeters shall be provided with separate fuse and toggle switch.

13.0 ANNUNCIATION

13.01 Each transformer rectifier shall be supplied with a continuous signal light, which will go out at loss of AC input. This light will be mounted on the top of the transformer rectifier unit. Arrangement shall be provided for giving visual indication of but not limited to the following.

i) Loss of power supply.

ii) Actuation of any protective device.

iii) Failure of auto mode.

iv) Fault on cable on primary and secondary circuit.

v) Under voltage and over voltage on supply side.

14.0 ENCLOSURES

14.01 All transformer rectifier units to be located in non-classified area shall be housed in air cooled enclosure vermin proof and shall be IP 54 as per IEC standards. Minimum cabinet thickness shall be 12 SWG. The enclosure shall be provided with a canopy over the top to protect the T/R unit.

14.02 Accessibility shall be provided by hinged and removable front and sides or by hinged doors and removable chassis. A plexiglas viewing window shall be provided to allow the meters to be read without opening the transformer rectifier unit.

14.03 The enclosure shall be supplied with an engraved warning label with the words “DANGER”. Transformer rectifier enclosure shall be furnished with gland plate mounted with double compression cable glands for the AC input, DC output and potential measurement cables as per the data sheet.

14.04 After fabrication the entire enclosure shall be sand blasted to Sa 2½ surface. An inorganic zinc primer shall then be sprayed to a total thickness of 3 mils. The finish coat shall be a dark grey shade of polyamide cured epoxy in three coats to achieve total thickness of fifteen (15) mils.

15.0 ENCLOSURE EARTHING

15.01 All normally dead metallic parts shall be electrically continuous. One earthing terminal suitable for 25 mm square cable connection shall allow their connection to power supply earthing and to earthing pit.

16.0 NAME PLATE

A permanently stamped metal plate with the following information shall be fixed to the outside of the case:
17.0 DATA SHEET OF T/ R UNIT

The parameters for which T/R set is to be sized [which represent minimum requirements] are given below.

A  A.C. Input Voltage : 220volts± 20%, 50Hz single phase
B  A.C. Input Current : 30 A max
C  DC Power Output : 3.75KW
D  DC Output Voltage : 50V
E  DC Output Current : 75A
F  Current rating for Diodes/ SCR's : 100% excess current capacity of T/ R unit.
G  Full load efficiency
   i) Transformer alone : More than 95%
   ii) Transformer rectifier assembly : More than 75%
H  Power Factor : 0.9 lagging
I  Insulation level : 2KV
J  Peak Inverse Voltage of Diodes/ DCRs : 2KV
K  Filtering Circuit : LC Filter
L  Ripple & Hum : Less than 5% at rated output.
M  Surge Diverters of Diodes/ SCR's : R-C circuitry
N  Lightning Arrestor : At both input and output side of the T/R unit of voltage rating 280 V RMS
   Max.Spark over voltage 3.0KV
   current discharge capacity: 10KA.
O  Protection : MCB having thermal overload and magnetic
   short circuit protection with back up HRC fuse for both input and output side in
   addition to separate HRC fuse protection
   for various power unit control elements.
P Construction: Floor mounted indoor type
Q Cooling: Air cooled
R Meters/ Instruments: 1No. DC Voltmeter – 0-60 V
1No. DC Ammeter – 0-80 V
1No. AC Voltmeter – 0-300 V
1 No. Corrosion Meter: ±XXX00 MV voltmeter with 10 megaohm input resistance with selector switch for measurement of RSP for each drainage circuit as well reference cell potential given by each permanent reference potential given by rail setting of potentiometer.
S Enclosure: As per specification.
T Cable Entry: Through double compression gland.
U Enclosure painting: As per Specification.
V Fabrication, Schematic Wiring diagram: Vendor to furnish.
X Spare Parts: Supply as per Specification.

18.0 TEST CERTIFICATES

18.01 The following test certificates/documents are to be furnished by the Vendor before shipment of material and equipments.

All major material and equipments e.g. T/ R unit, CP System Distribution Board, cables etc. shall be tested and inspected by BHEL or its representative.

Following routine tests shall be done by manufacturer as per any approved international codes.

a) Efficiency test of Transformer Rectifier Assembly at 25%, 50%, 75% and 100% rated current.
   Efficiency test of transformer alone after isolating rectifier at 100% rated current.

b) Heat run test for max. temp. rise test of winding at 100% rated current after continuous operation of 48 hours (min.)

c) Ratio and polarity test at 25%, 50%, 75% and 100% rated for all T/ R units.

d) Insulation resistance test at 2 KV between Primary and Secondary, Primary and earth, secondary and earth for all T/ R units.

e) The electronic current control feature of T/ R unit to be tested by varying supply voltage 25% and changing load resistance 100%.

f) The electronic current limiting feature of the T/ R unit to be tested by short circuiting positive and negative terminals of the T/ R unit and setting max. current limits at any desired values in steps of 3a.

g) Calibration tests of Ammeters & Voltmeters of all T/ R units.

19.0 DRAWINGS/ DOCUMENTS

19.01 Fabrication drawings and data sheet of T/ R unit with all dimensions, ratings and weight in final issue, including installation/ foundation arrangement details.

19.02 Front view and typical section of T/ R unit panel with arrangement of equipment, control, protection and metering.
19.03 Data sheet of all accessories and circuit element of T/ R unit including ratings.

19.04 Schematic and wiring diagram of T/ R unit circuitry including Auto/ Manual Mode of control.

19.05 Fabrication drawings, connection scheme details and data sheet of Distribution Board with all dimensions, rating and weights in final issue including mounting details.

ANNEXURE VII

TECHNICAL REQUIREMENTS

FOR

THERMIT WELDING
<table>
<thead>
<tr>
<th>TITLE</th>
<th>TECHNICAL REQUIREMENTS FOR CATHODIC PROTECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPECIFICATION NO.</td>
<td>PE-TS-XXX-510-E001</td>
</tr>
<tr>
<td>VOLUME NO.</td>
<td>II-B</td>
</tr>
<tr>
<td>SECTION</td>
<td>C</td>
</tr>
<tr>
<td>REV NO</td>
<td>00</td>
</tr>
<tr>
<td>DATE</td>
<td></td>
</tr>
<tr>
<td>SHEET</td>
<td>36 of 42</td>
</tr>
</tbody>
</table>
1.0 SCOPE

This specification covers the technical requirement and method/technique for cable attachment to pipe provided with cathodic protection system.

1.01 THERMIT WELDING

Thermite welding shall be used for cable attachment to steel or iron with metallurgically limited usage. This process enables copper to be welded to steel or iron without the use of welding equipment. The temperature of the reaction is such that the surface layer of base metal undergoes a metallurgical change by both heat treatment and partial alloying with the copper content of the thermit charge.

Because of the intense reaction, extreme care shall be taken in preparation and firing together with the correct choice of attached cable size, change and mould.

1.02 Both horizontal and vertical connections can be achieved in the following manner:

   a. Clean off a 50X50mm area to clean, bright dry metal
   b. Cut back 50mm of insulation from the cable; keep clean, dry and grease free.
   c. Insert cable into slot in bottom of mould and place squarely on the cleaned area.
   d. Break open the charge cartridge and upend the power into centre mould after placing metal retainer disc in bottom. Ensure that the fine starter powder which sometimes gets left behind in the container, is shaken onto the top.
   e. Hold mould firmly onto pipe, shut the lid, and spark off with a flint gun.
   f. Allow to cool for thirty seconds and remove mould.
   g. Tap off slag and test adhesion when cool by a sharp sideways rap with a 2 lb hammer.
   h. Carefully mould over the top using material compatible with the pipeline coating.
   i. The thermit welded joints shall then be appropriately encapsulated by epoxy encapsulation as stated elsewhere.

1.03 The same parameters shall apply for the brazing method and type of charge necessary for welding to advice on the bond size and type of charge necessary for welding to be approved at site (by the inspecting authority/ BHEL).

1.04 Each thermite weld connection will basically require the following equipment:

   a. Thermite well mold.
   b. Thermite weld metal.
   c. Thermite weld cap
   d. Steel disc.
   e. Copper sleeve
   f. Flint ignitor.
   g. Mould packing.
h. Epoxy encapsulation kit.

1.05 THERMIT WELDING EQUIPMENT

1.05.1 Connections for Cathodic Protection

i) Steel pipes

Place end of cable under centre of top hole. For weld to steel pipe smaller than 100mm, place end of cable even with far side of tap hole. On all type HA welds, pack cable opening with packing material. Hold down mould cover to prevent mould from tipping.

1.05.2 CARTRIDGE

i) For Steel Pipe

Cartridge supplied with starter power and metal retainer disc:

<table>
<thead>
<tr>
<th>Cartridge No.</th>
<th>Copper/ Steel</th>
<th>No in box</th>
</tr>
</thead>
<tbody>
<tr>
<td>F33-15</td>
<td>*2.5-10 sq.mm</td>
<td>20</td>
</tr>
<tr>
<td>F33-25</td>
<td>16 sq.mm</td>
<td>20</td>
</tr>
<tr>
<td>F33-45</td>
<td>25-35 sq.mm</td>
<td>20</td>
</tr>
<tr>
<td>F33-65**</td>
<td>50-70 sq.mm</td>
<td>20</td>
</tr>
</tbody>
</table>

Use sleeve with 2.5 sq.mm.

ii) For Iron Pipe

Cartridge No. Copper/ Steel No in box

<table>
<thead>
<tr>
<th>Cartridge No.</th>
<th>Copper/ Steel</th>
<th>No in box</th>
</tr>
</thead>
<tbody>
<tr>
<td>XF19-25</td>
<td>*2.5-10 sq.mm</td>
<td>20</td>
</tr>
<tr>
<td>XF19-45</td>
<td>16-25 sq.mm</td>
<td>20</td>
</tr>
<tr>
<td>XF1965</td>
<td>35-50 sq.mm</td>
<td>20</td>
</tr>
</tbody>
</table>

1.05.3 ACCESSORIES

Moulds: Type HA for Steel, Type HB for Iron, Type HC for trough (50-100 fires per mould)
Flint Cun, Scrapper, Cu sleeves for 2.5 sq.mm cable, Wire Brush, Rasp.
ANNEXURE VIII

TECHNICAL REQUIREMENTS

FOR

SURVEY
1.0 Resistivity Measurement & Calculations:

1.01 Wenner’s 4 pin method shall be used to carry out soil resistivity measurement.

1.02 Care should be taken that measurements are not influenced by presence of overhead lines over earth currents in the area. Soil resistivity measurements shall be made at least 15M away from underground metallic structures if any along ROW or anode ground bed locations.

1.03 The depth of insertion of each pin while measuring resistivity shall be 1/20th of the pin spacing.

1.04 Soil resistivity shall be computed by the following relation:

\[ P = 2 \frac{naR}{A} \]

Where

- \( P \) - Average Resistivity of soil depth of ‘a’ metres in ohm-metres.
- \( A \) - Spacing between two consecutive pins in metres.
- \( R \) - Resistance in ohms displayed by Megger.

2.0 Soil Resistivity Measurement along ROW/ Piping Corridor

2.01 Generally the observations shall be made enclosing the soils immediately surroundings the pipeline route between the central electrodes where right of way has been cleared.

2.02 At places where right of way has not yet been cleared, measurements shall be made right over the defined locations to account for cutting filling also. All measurements shall be taken at right angles to ROW unless otherwise asked for by Project Engineer at site.

2.03 Each spot shall be investigated so as to obtain average soil resistivity up to the following depths:

- 0.5, 1.5, 3.0 & 6.0 Metres

2.04 All the river creek beds and other major water crossing/ marshy lands, swamps should be so chosen for resistivity observations so as to obtain resistivity of the soil at river/ creek beds or marsh lands.

3.0 Soil Resistivity Measurement on Anode Ground Bed

3.01 After completion of soil resistivity survey along ROW and preparation of soil resistivity plot (resistivity contour), based on the resistivity values, two (2) anode grounded plots shall be selected in consultation with and as directed by the Project Engineer for each proposed CP station.

3.02 After marking of the various anode ground bed plots, each plot shall be subdivided into three subplots, each of which shall then be investigated for resistivity measurement at the following pin spacings:

- 1, 2, 3, 4, 5, 6 & 10 metre.

Thus each anode ground subplot shall have a set of seven observations at an average with a view to determine the nature of soil level and soil stratification and also possible water table depth.

4.0 Soil Resistivity Survey Instrument:

- **Nomenclature**: Battery Powered solid state 500 volts 5 terminal earth megger.
- **Range**: 0-01, 0-1, 0-10, 0-100 ohms.
- **Accuracy**: With +/- 1% of maximum value of selected range.
Sensitivity : Two position switch for low and high balance sensitivity shall be prepared. Instrument should incorporate design features for max. A.C. & D.C. ground current rejections.

Temp. Range : 0-60°C fully temperature stabilised.

Circuitry : Solid state suitable for rough and rugged use. Suitable for 2, 3 & 4 pin application
ANNEXURE IX

Guidelines for shipping and sea-worthy packing
(spec. no. PE-TS-XXX-501-A-100)