TECHNICAL SPECIFICATION
FOR
CATHODIC PROTECTION SYSTEM

SPECIFICATION NO.: PE-TS-XXX-509-E003 (REV-00)

VOLUME II

BHARAT HEAVY ELECTRICALS LIMITED
POWER SECTOR
PROJECT ENGINEERING MANAGEMENT
NOIDA – 201301
STANDARD TECHNICAL REQUIREMENTS
1.00 SCOPE

1.01 GENERAL

a) This specification covers the following activities for cathodic protection system:

i) Carrying out required corrosion survey and collection of data for design and implementation of cathodic protection systems.

ii) Implementation of cathodic protection systems by interpretation of survey data, detailed design, engineering, manufacturing, fabrication, assembly, inspection and testing at manufacturers works, proper packing and delivery at site, unloading and storage at the site, execution of all associated civil works, installation of various equipments, inspection, field testing & commissioning as per the approved commissioning procedure, performance testing at site and handing over to the owner / BHEL.

iii) Periodic monitoring of the system for the specified period.

iv) 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.

b) The “design” shall broadly cover the selection of components, materials, sizes etc. for the equipment of supply in vendor’s scope. Complete responsibility of establishing the correctness of equipment design rests with the vendor.

c) It is not the intent to specify here all the details of design and manufacture. However, the equipment shall conform in all respects to high standards of design, engineering and workmanship, and shall be capable of performing the required duties in a manner acceptable to Engineer / purchaser, who will interpret the meaning of drawings and specifications and shall be entitled to reject any work or material, which in his judgement is not in full accordance herewith.

d) Make of all equipment and components shall be to the approval of purchaser.

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

1.02 ENGINEERING

a) Specification also covers the aspect of System Design Engineering generally termed as “Engineering”.

b) Engineering in vendor’s scope, shall include design of complete cathodic protection system for equipment specified in the specification. The aspect of engineering covers preparation of design documents, connection scheme, overall layout drawings, quantity estimation, cable layout drawings, cable schedules and all associated design work not specifically mentioned in the specification.

c) Complete engineering shall be as per the guidelines of purchaser and shall be subject to the purchaser’s approval.
1.03 The requirements given in enclosed drawings, documents and Data Sheet A form part of this specification and shall be fully complied with. In case any discrepancy arises, the requirements of Data Sheet-A shall prevail.

1.04 In case of any deviation, the bidder shall indicate the same clause-by-clause in the enclosed “Schedule of Deviations”. In the absence of duly filled schedules it will be construed that the bid conforms strictly to the specification.

2.00 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 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. Non-familiarity with the site conditions will not be considered a reason either for extra claims or for not carrying out the work in strict conformity with the drawings and specifications.

2.03 Every item of work and supply shall be subject to Engineer-In-Charge scrutiny, supervision and approval. Any work carried out or supplies effected without such approval shall stand automatically rejected and his claim for compensation for such unauthorized work shall be null and void.

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 and/or Sacrificial anode Cathodic Protection (SACP) system as applicable. 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 once in a month.

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.

3.00 SPECIFIC REQUIREMENTS FOR C.P.SYSTEM WORKS

3.01 BHEL/OWNER shall have the right to inspect the following:
- Workshop & production facilities available with contractor or its tie up agency.
- Fabrication/testing of material/equipment to be supplied by contractor or its sub-vendor.
It shall be Bidder's responsibility to arrange access for BHEL/OWNER Personnel for such visits. All costs related with travel, boarding, lodging for BHEL/OWNER personnel for such visits (if any) shall be borne by BHEL/OWNER.

3.02 ‘A’ class Electrical CP System sub-contractor license is essentially required as per regulations laid by electrical inspector of the state for electrical jobs. The CP System subcontractor shall arrange for the same. Any approval from electrical inspector required for the electrical installation shall be in CP System sub-contractor's scope.

3.03 Material Supplied By Owner

No material for C.P. System shall be supplied by owner.

3.04 Material Supplied by CP System sub-contractor:

The CP System sub-contractor shall procure supply all materials, equipment and consumables required for the work in his scope. Technical specifications of major items are given in section 3.0 for "Job specification for C.P. System", of this document. Supply of all balance materials, consumables not covered in section 3.0 for "Job specification for C.P. System", but required for completion of work as per this specification shall be entirely CP System sub-contractor's responsibility. The rates quoted for the execution of the Contract shall be inclusive of all CP System sub-contractor supplied material and equipment.

3.05 Temporary cathodic protection:

The CP System sub-contractor shall provide sacrificial anode type temporary cathodic protection (if specified) for one year in case main cathodic protection is impressed current type. Supply, erection & commissioning all materials, equipment and consumables required for this work in his scope. The rates quoted for the execution of the contract shall be inclusive of temporary CP System as required.

3.06 Warranty

EPC Contractor / CP System sub-contractor needs to provide design guarantee for the system as per codes and standards & the protection criteria mentioned in the section Design basis/Philosophy of this document. CP System sub-contractor needs to replace/ repair or reinstall free of cost any material/equipment supplied or installed by him in case it fails to operate due to defective material or workmanship as per requirements of this specification within 12(Twelve) months from the date of issue of completion certificate and acceptance of the C.P. System by Owner. CP System sub-contractor shall replace at his own cost if any item found defective or missed before handing over the system to owner.

3.07 Construction Aids, Equipment, Tools and Tackles

CP System sub-contractor shall be solely responsible for making available for executing the work, all requisite construction Equipment, special Aids, tools, tackles and testing equipment and appliances, all instruments including automatic Programmable current interrupters required for commissioning and interference testing of the system. Such construction equipment shall be in first class operating condition. Any discrepancies pointed out by Owner/BHEL shall be immediately got rectified, repaired or the equipment replaced all together by CP System sub-contractor. Owner/BHEL shall not in any way be responsible for providing any such equipment, machinery tools and tackles etc. The Owner/BHEL reserves the right to re-arrange such deployment depending upon the progress and priority of work in various sections at no extra cost to Owner.
3.08 Transportation, Packing and Handling

CP System sub-contractor shall be responsible for transportation of all equipment/materials required for C.P. system work and unload the same at allotted area at site. To protect all the material during period of despatch, storage and erection against corrosion, incidental damage due to vermin, sunlight, rain, high temperature, humid atmosphere, rough handling in transit and storage in open during monsoon including delays in transit. Bidder shall be responsible for any damage to equipment/material due to above reasons.
4.00 DESIGN PHILOSOPHY/ BASIS FOR CATHODIC PROTECTION SYSTEM

4.01 Codes and Standards
The entire work shall be performed as per the following codes/standards.
- NACE : RP-0169-97, RP-0285-95
- BS : 7361 Part I-1991 (Formerly CP 1021-1973)
- VDE: 0150, protection against corrosion due to stray currents from DC installations.
- DIN : 30676
- IEC/NEC : Relevant codes
- Indian electricity act and rules framed thereunder.
- Fire insurance regulations.
- Regulations laid by Chief Electrical Inspector of State.
- Regulations laid by Chief Inspector of Explosives.
- Regulation laid by Factory Inspector of State.
Wherever the requirements in this specification are in conflict with any of the above standards, the requirements of this specification shall be binding.

4.02 Generally any one of the two cathodic protection system namely impressed current CP (ICCP) or Sacrificial anode CP (SACP) is used for cathodic protection of metallic structure.

4.03 SCHEME FOR IMPRESSED CURRENT CP SYSTEM

(a) Impressed current cathodic protection is to be provided for prevention of soil side corrosion of all underground pipelines, underground vessels, mounted storage bullets and bottom plate of the storage tanks under the scope of work. For details, refer BOQ specified somewhere else in the specification.

(b) Impressed Current Cathodic Protection System (ICCP) shall typically consist of:

- Required numbers of close distributed long line MMO wire anode prepacked with coke breeze at Anode manufacturer’s factory should be considered as anode for impressed current CP System. The make/model of MMO wire anode to be supplied shall be either “MATCOR Make SPL™-FBR-16” or Covalence /Tyco/ Berry Plastics (USA) Make (Anodaflex-3000 or 3020) or equivalent make. The type of Anode and anode bed for the ICCP system shall be in conformance with BS 7361 Part 1.

- 1 No. anode junction box per CP Station.
- 1 No. T/R unit per CP station.
- Single core, 10 sqmm stranded copper conductor, PVC insulated, overall FRLS PVC sheathed armoured cable required for connection between anode and junction box.
- 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.
- 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.
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.

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

All civil, structural and electrical materials required for installation of Impressed Current Cathodic Protection System (ICCP) system.

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

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

Required zinc grounding cells and Kirk cells.

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

Required numbers of permanent reference cells.

Required number of test stations shall be provided for the ICCP system for system monitoring and testing.

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

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

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.

C.P.System of foreign structure within the plant complex such as RCC pavements, RCC foundations, earthing grids, other U/G piping which are not intended to be protected are excluded from the scope of this work.

Close distributed long line MMO wire anode piggyback connected with anode lead cable, factory pre-packed with coke breeze or tubular MMO anode should be considered as anode for impressed current CP System for all UG Piping.

Close distributed long line MMO wire anode piggyback connected with anode lead cable, factory pre-packed with coke breeze should be considered as anode for impressed current CP System for all and for underground vessels, mounded storage bullets and bottom plate of the storage tanks where design temperature is 65°C or more.

For underground vessels, mounded storage bullets and bottom plate of the storage tanks where design temperature is upto 65°C, either Close distributed long line MMO wire anode piggyback connected with anode lead cable and prepacked with coke breeze at Anode manufacturer’s factory or conductive polymer anode prepacked with coke breeze at Anode manufacturer’s factory should be considered.

All piping & structures which shall be cathodically protected shall be fed from outdoor type, natural air cooled, Transformer-Rectifier unit (T/R Unit) either Classified/explosion proof or non-Classified (IP-55) type depending on the area classification of the outdoor location of
the TR Unit. The rating of the TR Unit shall be 75V/75A, 50V/50A or 25V/25A as per load requirement.

(h) Separate T/R Unit should be considered for all different type of structures to be protected such as pipelines, underground vessels, mounded storage bullets and bottom plate of the storage tanks to be located at the OFFSITES & UTILITIES.

(i) T/R Unit shall have one outgoing positive header cable, which may be terminated to CDB, one each positive header cables from the CDB may be terminated to several AJB to be installed along the pipeline route or near the structures to be protected. T/R Unit shall have one out going negative header cable which shall be connected to 1 No. of cathode junction box cum test station (CJB). Each CJB cum test station (CJB) shall be located along the pipeline route or near the structures to be protected for its drainage connection and potential measurement. Minimum two drainage cables and two measurement cables from each pipeline or from each structure to be protected shall be terminated to CJB.

(j) Power supply for the T/R Unit shall be drawn from the nearest switchboard (Customer scope). One or more 125A/63A, 415V, TPN circuit breaker/ Switch fuse unit need to be considered at each S/S for the power supply to CP System. CP SYSTEM SUB-CONTRACTOR need to lay one 3-phase, 4-wire power supply cable from this circuit breaker/ Switch Fuse unit outlet to one outdoor type PDB near the T/R Unit location for distribution of power to the T/R Unit.

(k) Monitoring of C.P. System performance shall be done by installation of required number of permanent reference cells distributed along the piping route or at each structure to be protected for each TR Unit. The reference cell cables and the measurement cables from each piping/structure shall be routed through the respective cathode junction box (CJB) or test station to a single Monitoring Junction Box (MJB) for each T/R Unit, which shall be located near the T/R Units and have the provision of measurement of structure to soil potential. Also for monitoring of structure to soil potentials at the T/R unit, monitoring cables consisting of reference cell and measurement cables shall be laid between MJB and T/R unit for connection of at least three reference cells to T/R Unit panel.

(l) All Cable laying should be done on existing overhead cable trays/cable trenches wherever possible. Underground Cable laying in paved/unpaved areas should be done as per BHEL/ owner approved recommendation wherever overhead cable trays/cable trenches are not available. Thermit welding shall do connection of drainage cables and measurement cables to the Vessel & piping.

(m) Computerized central monitoring and control of all T/R units and the permanent reference cells shall be done with the help of microprocessor based CP System remote terminal unit RTU/PLC. The central control and monitoring unit shall be located at any one of the Electrical S/S or control room as per the choice of the OWNER. Central control and monitoring unit shall communicate with all the RTU/PLC as master slave system. The communication link between the RTU/PLC and Central monitoring and Control station should be cost effective GSM based wireless technology / RS485 / telephone / fibreoptic / ethernet communication whichever is decided by BHEL/ OWNER as the communication network.

(n) Contractor should design, procure and install the requisite communication system and the cables required for this purpose. Necessary dedicated Telephone lines shall be allotted by OWNER at one centrally located electrical substation for CP System central control and monitoring purpose in case telephone communication is considered between the remote RTU/PLC and central monitoring and control station. Each T/R Unit shall accept set point signals for DC Voltage and DC Current from Remote Monitoring & Controlling Panel and accordingly shall control its output from 0 to 100%.
4.04 SCHEME FOR SARIFICIAL ANODE CP SYSTEM:

Sacrificial Anode CP System shall typically consist of

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

b) Required number of anode and cathode junction box.

c) Single core of required cross-section stranded copper conductor, XLPE insulated, overall FRLS PVC sheathed armoured cable required for connection between anode and junction box.

d) Single core of required cross-section stranded copper conductor, XLPE insulated, overall FRLS PVC sheathed armoured cable for connection between cathode junction box and pipeline.

e) 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.

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

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

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

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

j) 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.

k) Complete permanent protection of casing and carrier pipelines using additional zinc anodes at each encased pipe crossing.

l) 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.

m) 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 purchaser’s approval.

4.05 C.P. System shall involve detail engineering, procurement, installation, testing, commissioning considering the following:

a) Transformer/Rectifier (T/R) units: T/R unit shall be of 25V/25A, 50V/50A, 75V/75A capacity depending on the current requirement, oil cooled outdoor plinth mounted and classified/non-classified type depending on the area classification of the location for outdoor installation or air cooled non-classified type for indoor installation. The enclosure of T/R units
shall be as per relevant IEC/NEC codes as per the location of the installations. All T/R units shall be installed under a sun/rain shed if installed outdoor. Approach steps to be provided for all outdoor type oil cooled T/R units coming in low-lying areas.

b) Anode bed:

i) For U/G piping: Anode Beds to be employed for C.P. System of U/G piping shall be close continuous string anode, MMO wire anode, piggyback connected with anode lead cable, factory pre-packed with coke breeze or tubular MMO anode (as specified). For close continuous string anodes, the length of anode string shall be same as length of U/G pipe for single run of pipe. In case of parallel run of pipes, the no. of continuous anode strings to be considered shall be as per discretion of BHEL/OWNER depending on factors such as diameter of pipes, congestion of the area etc. However following general guideline shall be considered while deciding the number of anode strings for parallel run of pipelines:

- One string for max. two lines when any one or all the lines are upto 6 inch diameter pipeline.
- One string for max. one line for above 6 inch diameter and upto 30 inch diameter pipeline.
- Two strings for each line for line size above 30 inch diameter and upto 70 inch diameter pipeline.
- When pipeline diameter is more than 70 inch and number of pipeline is one or more, the number of string anode to be considered shall be decided by considering cathode structure current density 30 mA/sq.m and anode current capacity 30mA/m.
- When more than one string is considered for parallel run of pipes, each string shall be preferably laid in different trench with suitable markers for their easy retrieval in future.

Each continuous anode string shall be of 300m (max.) length and shall be fed at both ends from a single T/R Unit using same or different anode junction box. String anode shall be laid laterally along the pipe axis at a distance of 2D or 500mm from the pipe whichever is decided by BHEL/OWNER during review of detailed engineering. For mechanical protection of the string at unpaved areas one layer of brick shall be laid along the string after back filling with soil by 150mm. The axis of the brick shall be perpendicular to the axis of the anode string. For future access of each anode string at paved areas, concrete slabs sealed with cement shall be laid along the string after back filling with soil. Care should be taken to ensure that anode string does not touch the structure to be protected or any foreign structure. Continuity test of the string and short circuit test of the string with structure intended to be protected as well as foreign structure shall be carried out before energizing the C.P.System. In case any abnormality is found during this test, CP System sub-contractor needs to do needful to rectify the fault before energizing the system.

ii) For U/G vessels: RCC pit shall be provided for the U/G vessel, Anodes employed for C.P. System of U/g vessels shall be mixed metal oxide coated on titanium wire anode, piggyback connected with anode lead cable, factory pre-packed with coke breeze or conductive polymer anode prepacked with coke breeze at Anode manufacturer's factory to be considered as per the temperature criteria mentioned vide section 2.2, scheme for ICCP system. The anode strings shall be located within the RCC pit.

Specific installation requirements of String Anode shall be as follows:

- Anode strings shall be installed in the sand cushion surrounding the vessel at a distance of 300mm from the vessel.
- Separation distance between consecutive String anode loop shall be uniform.
- Length of each longer side of the loop string anode shall be same as the length of the vessel + 0.6m.
- Minimum 4 No. of strings should be considered for each vessel

iii) **For Tank Bottom plates:** Anodes employed for C.P. System of tank bottom plates shall be mixed metal oxide coated on titanium wire anode, piggyback connected with anode lead cable, factory pre-packed with coke breeze or conductive polymer anode prepacked with coke breeze at Anode manufacturer’s factory to be considered as per the temperature criteria mentioned vide section 2.2. The anode strings shall be laid in the sand cushion or soil under the tank bottom plate extending straight from one end to other end of the tank rim. Following guide lines shall be considered for installation of String Anode for coated tank bottom plates:
  - Separation distance of String anode from bottom plate to be protected shall be 1000mm.
  - Maximum spacing between consecutive anode strings = 1.5m. In case 1m space is not available between bottom plate and string anode, suitable shielding arrangement to be provided on string anode so that it does not touch the bottom plate. For such case, Maximum spacing between consecutive anode strings shall depend on available separation distance of String anode from bottom plate and the same shall be decided by BHEL/Owner at the time of detail engineering. In case tank is mounted on RCC pile foundation, one insulating PE film is to be laid on the pile cap before sand filling of the cap to ensure minimum C.P. system current is diverted to the pile cap. Contractor need to lay one layer of insulating P.E. film of thickness 1.2mm on the concrete surface of the RCC cap before sand filling for the tanks mounted on RCC pilling. The Roll size of the P.E. film shall be decided by the contractor. While laying, overlap of 5mm is to be made between consecutive longitudinal P.E. strips. Also, the overlaps need to be sealed using blow lamp or plastic welding method.

iv) **For bullet:** Anodes to be considered shall be close continuous distributed type mixed metal oxide wire anode, piggyback connected with anode lead cable, factory prepacked with coke breeze or conductive polymer anode prepacked with coke breeze at Anode manufacturer’s factory to be considered as per the temperature criteria mentioned vide section 2.2. The anode strings shall be laid in the sand cushion of the bullet backfill, in the form of several horizontally laid strings surrounding the bullet. The general specifications of mixed metal oxide coated on titanium wire anode factory prepacked with coke breeze is enclosed in SECTION 3.0. Following guide lines shall be considered for uniform current distribution:
  - Separation distance of String anode from bullet to be protected shall be 1.0m, two rows of anode string shall be considered for each bullet, number of strings in each row shall be same as the diameter of the bullet.
  - Vertical separation distance between each consecutive anode string shall be 1.0m in each row of anode string.

Free ends of each anode string should be connected to AJB located at each end of the bullet. Thus 2 No. of anode lead cables from each anode string shall be terminated to AJB. A trained cable jointer need perform the anode lead cable to anode string joints, at factory or at field. Sand resistivity need to be considered for the Bullet CP System design as 200 ohm- m. The bullet shall have suitable paint for the soil side corrosion protection.

c) **Junction Boxes:** The enclosure of AJB & CJB shall be classified type as per Area classification and relevant IEC/NEC codes given in enclosed spec. Anode strings should be designed and grouped for each AJB in such a manner that approximately uniform anode...
current is discharged through each terminal. While deciding no. of Anode leads for each AJB, at least two nos. of cable entries and cable terminals should be kept spare at each AJB for connection of Anodes as per supplementary design, if required. In case supplementary design is not required in certain areas, the spare cable entries should be closed with a threaded plug.

d) Cables: Cables for C.P. System shall be as per BHEL standard specifications.

e) Power Distribution Board (PDB): The Power distribution board (PDB) shall be plinth mounted outdoor type if TR Unit is installed out door and shall be installed at classified locations near a single or group of T/R Unit under a sun/rain shed. The enclosure of shall be classified type as per relevant IEC/NEC codes. The Power distribution board (PDB) shall be composed of one no.3 phase, 4-wire 125A/63A, incoming MCCB and 12/3 nos. 1 phase, 63A outgoing MCB. The incoming switch shall be 4-pole and outgoing switches shall be 2-pole. The MCCB and MCB shall be suitable for motor load application and shall be of BHEL/owner approved make. 4 Nos. of 25x5mm tinned copper bus bar shall be used which should be tapped by PVC tape of red, yellow and blue colours for identification of the three phases and black colour for neutral. Wiring inside PDB shall be done using 50mm², 1-core, copper conductor, PVC insulated, unarmoured cable between TPN switch neutral and neutral bus whereas rest of the wiring shall be done by 25mm², 1-core, copper conductor, PVC insulated unarmoured cable. All single core cables shall be used red, yellow and blue coloured for phase connections and black coloured for neutral connection. All cables terminations shall be through Tinned copper cable lugs of matching cable size. All cable entries to the PDB panel shall be through Aluminium single compression glands. One gland for required size, 3-phase, 4-core incoming cable connection shall be provided at left side bottom of the panel, 12/3 glands to be provided at right side bottom of the panel for outgoing cable connections for 63A PDB. The outgoing cables shall be 25mm² (min), 1-phase, 2-core aluminum conductor cables. Size of the PDB Panel enclosure shall be adequate to accommodate all components easily and shall be made of 2 mm sheet steel. Two nos. hinged front shutters shall be provided. The shutters shall be screwed to the panel enclosure structure at the centre in addition it shall have lockable handles. Painting details of inside and outside surfaces of the PDB panel shall be as follows: After fabrications the entire enclosure shall be sand blasted to a SA2½ surface. An inorganic zinc primer shall then be sprayed to a total thickness of 3 mils. The finish coat shall be of polyamide cured epoxy in three coats to achieve total thickness of 15 mils. The finish paint shade shall be as per choice of BHEL/OWNER specified in Section-C. CP SYSTEM SUB-CONTRACTOR shall prepare the layout/construction drawings and a prototype of PDB showing internal terminal arrangement and wiring arrangements and submit to OWNER/BHEL for approval before procurement/ installation of the same at site.

f) Cable to cable straight through joint: As far as possible any straight through joint shall be avoided for any cable run, however for unavoidable situations the straight through joint kit of any standard manufacturer as per OWNER/BHEL approval may be considered for jointing cables.

g) Thermit Weld Connection: All cable-to-structure connections shall be made utilizing the exothermic weld process.

h) Current distribution box (CDB): A current distribution box shall be employed to feed C.P. current to multiple vessels from a single T/R unit. One no. of CDB shall be connected with single T/R Unit and multiple vessels. The CDB shall be located in the classified area if installed outdoor or in the non-classified area if installed indoor and its enclosure shall be as per Area classification and relevant IEC/NEC codes. The CDB shall have the provision of resistors to control the anode bed current for each tank. The current shall be fed to the anode
bed of each tank from the CDB via local Anode junction box of either 1no. or 2nos. installed for each tank/vessels. Current distribution box shall comprise of one tin-copper bus bar of cross-section 25mm x 5mm of required length. The bus bar is to be connected with 4 nos. of variable coiled stripped resistor of CRESSALL make type ZO or equivalent. Connection to the resistor shall be through welded lugs to the resistor coil having tapping at 25%, 50%, 75% and 100%. The rating of resistor shall be 0-1 ohm, 50 Amp, 2500 watts. Each resistor shall be connected with manganin shunt of rating 50 Amp, 50 MV. The terminals shall be made of 8mm diameter stud/double nut-double spring washer of 8mm-dia stainless steel. Incoming cables will be terminated in the bus bar and each outgoing cable will be connected to the shunt. All outgoing cables shall terminate in the respective anode junction box of each vessel. All incoming and outgoing cables shall be of 95mm², 1-core, aluminium conductor armoured cable. All cable terminations to the box shall be done using Dowell make lugs suitable for both aluminium and copper conductor. Cable glands should be aluminium, double compression, non-classified type. The terminal board for mounting the accessories shall be phenolic laminated of thickness 10mm. The enclosure shall be painted with polyamide-cured epoxy coating application of 375- micron thickness after surface preparation of SA 2½ and application of inorganic zinc primer. The colour of the final shade shall be yellow. Out of the outlets for positive header cable, if all the outlets are not utilized, the same shall be plugged with threaded MS plug. Vendor shall prepare the layout/construction drawings and a prototype of CDB showing internal terminal arrangement and wiring arrangements and submit to OWNER/BHEL for approval before procurement/installation of the same at site.

i) **Monitoring Junction Box (MJB):** MJB shall have provision for measurement of piping to soil potentials for all piping and shall be installed near the T/R Unit under a sun/rain shed. For measurement of piping to soil potentials multi-core cable (25-core x 1.5 mm², Cu, one-run or 10-core x 1.5 mm², Cu, two-run) to be laid between CJB and MJB. Multi-core cable (10-core x 1.5 mm² ,Cu) to be laid also between MJB and T/R Unit for measurement of at least two reference cell potential at the T/R Unit. The enclosure of MJB shall be classified type as per relevant IEC/NEC codes. Monitoring junction boxes (MJB) will be installed near the T/R Unit and shall be required for monitoring potentials of multiple piping. The enclosure for the MJB shall be of IP-55 construction made of 12SWG (2.67) W.T. sheet steel if installed indoor and classified type if installed outdoor. CP System sub-contractor shall prepare the layout/construction drawings and a prototype of MJB showing internal terminal arrangement and wiring arrangements and submit to OWNER/BHEL for approval before procurement/installation of the same.

j) **Permanent Reference cells:** For monitoring the performance of the CP System following number of the Permanent Cu/CuSO4 reference cells shall be considered:
   i) Permanent Cu/CuSO4 reference cells shall be installed at a distance of 300mm from the UG Piping for monitoring of C.P.System. Minimum 10 no. of reference cells to be installed for piping at equidistant locations for each TR Unit.
   ii) Minimum 4 no. of reference cells to be installed for each Vessel
   iii) Minimum 3 no. of reference cells to be installed for each Tank upto 30m diameter and Minimum 5 no. of reference cells to be installed for each Tank above 30m diameter.
   iv) Minimum 16 no. of reference cells to be installed for each bullet at equidistant locations.

k) **Shelter/shed for weather protection of TR Unit, PDB, MJB, CDB, CJB, etc.:** Different groups of TR Unit, PDB, CDB, CJB, MJB, RTU/PLC Panel, local telephone exchange etc. if located outdoor and at different locations of the plant shall be installed under a shelter for its weather protection. The shelter should be covered from top and open at all four sides. Removable steel gray painted 16 SWG sheet metal shall be screwed to angle iron frame as top cover. The angle iron to be considered for the frame shall be of size 2 inch (Min.). The top cover structure shall be screwed to 75 mm diameter vertical supporting pipes grouted at
an interval of 2m. RCC ramp foundation is to be made for grouting of the vertical supporting pipes. The maximum height of the shelter shall be 3m from the grade level. The foundation depth shall be 2m (Min.). RCC pavement 4 inch deep is to be made for the floor of the shelter along with RCC cable trench. The RCC cable trenches should be filled with sand after cable laying to avoid possibility of accumulation of hazardous gas at the bottom of the trench. The detailed design of the shelter/shed need to be prepared by contractor and should be furnished to BHEL/OWNER for approval before execution at site.

l) Portable half cell: Portable Cu-CuSO₄ reference cells shall be provided for measurement of Pipe/structure to Soil potential for the pipeline/structure.

m) Grounding Cells: Zinc grounding cell, with minimum 10 m length of cable, shall be provided at each Insulating Joints. Suitable TLP shall be provided at each Grounding cell location.

n) Solid State type Polarisation cell: Solid State type Polarization cells shall be installed near HT line crossings and at MOV locations in the mainline. Suitable TLPs are to be provided at these locations.

o) Surge Arrestors: Surge arrestors shall be provided at each insulating joints inside the E type TLP Box. Necessary cables are to be provided by the contractor accordingly.

p) Cable to Pipe Connection: All cable connections to pipe for Cathode & Permanent Half cell cable shall be through an approved exothermic/pin brazing process. In no case cable shall be connected at the seam of the pipe.

4.06 Design basis for C.P.System:

a) No Insulating joints shall be installed to isolate any incidental structures from C.P.System within Battery limit. Hence the structures intended to be cathodically protected shall be in electrical continuity with many foreign structures within the plant complex such as RCC pavements, RCC foundations, earthing grids, other U/G structures, which are not intended to be protected. The C.P. current requirement, therefore shall be governed by following factors:
   - Surface area and coating quality of structures to be protected.
   - Surface area and surface condition of nearby foreign structures.
   - Relative position of anode between foreign structure and structure intended to be protected.

To take care of such situation C.P. System shall be designed & installed in two stages by providing one preliminary design and another supplementary design as follows:

i) Preliminary design: A preliminary design shall be made based on the scheme mentioned in section 2.2 above considering either conductive polymer anode or mixed metal oxide wire anode. The quantities required for T/R units, Power Distribution Boards, anode beds of various configurations, Junction boxes (AJB, CJB, MJB, CDB etc.), Cables of various sizes, Thermit weld connections, and any other materials as required shall be calculated by CP SYSTEM SUB-CONTRACTOR. The locations of T/R units, Distribution Boards, anode beds of various configurations, Junction boxes (AJB, CJB, MJB, CDB etc.), Cables of various sizes, Thermit weld connections, shall be marked by CP SYSTEM SUB-CONTRACTOR in appropriate layout drawings and shall be submitted along with Detail engineering package to OWNER/BHEL for approval. The T/R Units, PDB, CDB and MJB shall be installed at one location under a common sun/rain shed in non-classified area near the Vessel & piping. The power supply for the T/R Unit/PDB shall be drawn from the identified cubical of the electrical
substation nearest to the bullets. The locations for installation of all C.P. system materials/equipment shall be verified at site by OWNER/BHEL to check the practical feasibility of installation as well as its suitability for optimum/effective performance as envisaged in the design. CP SYSTEM SUB-CONTRACTOR shall start installation work of C.P. System only after site verification and approval of locations by OWNER/BHEL at site. Detailed Engineering works to be performed by CP SYSTEM SUB-CONTRACTOR are mentioned in Section 2.4. After completion of installation work, CP SYSTEM SUB-CONTRACTOR shall carry out testing/commissioning activities in presence of OWNER/BHEL.

ii) Supplementary design: After energising C.P. System as per preliminary design, the unprotected/under protected and over protected areas shall be identified and a supplementary design is to be made to bring all structures intended to be protected within acceptable potential limits. For identification of under protected/overprotected areas, at first natural Str. To soil potential is to be taken at all test points in presence of OWNER/BHEL. Then the system as per preliminary design shall be energised at different current levels. For each current level, protection potential and protection span of cathode structure nearest to as well as remotest to each anode bed shall be observed until predetermined current limits of Anodes or T/R units are reached or desired protection potential levels are achieved. These observations shall be recorded in a tabular form or graphically plotted and to be submitted to OWNER/BHEL for review. OWNER/BHEL after review/interpretation of the instant commissioning results or within 6 months of the polarization period of the C.P.System, shall decide whether any additional anode bed or additional T/R unit is required to be installed or whether there is requirement for disconnection of some anodes/anode beds or any other remedial measures and the CP System sub-contractor shall update the C.P.System accordingly at no additional cost and within a specified time acceptable to BHEL/OWNER. In case it is decided to install additional anodes then 6A capacity MMO tubular anodes need to be installed at the suitable locations as decided by BHEL.

iii) The following criteria shall be followed to determine the protection levels:

- Maximum allowable vessel to soil potential with respect to Cu/CuSO4 ref. Cell: 2.50V (ON) or –1.10V (Instant OFF)
- Minimum allowable vessel to soil potential with respect to Cu/CuSO4 ref. Cell: 0.850 V (ON) or -100mV polarization shift (Off) or -300mV potential shift from initial native potential to the C.P. potential. Discretion to use any of the criteria shall solely rest with Owner/Owner's Representative.
- Interference Criteria: +100mV positive shift

b) Design life of Anode = 25 years (minimum).

c) Adequate Test station/test points are to be considered including one each at the nearest point as well as remotest point from each anode to ensure adequate potential level of vessels intended to be protected.

d) While deciding number of modular type T/R units, considerations must be given to see no T/R unit is loaded more than 75% of its rated output voltage & current capacity throughout design life while feeding load to a single or group of anode beds.

e) While making preliminary design CP System sub-contractor should make the entire endeavor to ensure the adequacy of the design so that the requirement of supplementary design is bare minimum.

f) For continuous string/wire anode the anode current capacity shall be considered 30mA/m for the design purpose.
g) Identification and mitigation of interference between structures to be protected as well as between the structures to be protected and foreign structures need to be carried out by CP System sub-contractor as per the requirements of the codes mentioned in this document.

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

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

j) Earthing of all T/R Units, PDB, CDB, JUNCTION BOXES, Vessel & piping, Vessels & Bullets need to be done by connecting the same with plant earthing grids, wherever plant earthing grids are not available nearby, a separate earth pit approved by OWNER/BHEL may be considered by CP System sub-contractor.

k) To avoid cable damage in the long run, all cables are to be laid at the cable trays wherever possible; underground cable laying should be considered only when no cable trays are available nearby. All C.P.System cables need to be laid at power cable trays, all multi core-monitoring cables may be laid in either electrical or instrumentation cable trays whichever is available.

l) For road crossing of C.P.System cables, suitable RCC duct or PVC PIPE duct embedded in concrete at proper depth need to be prepared by CP System subcontractor. CP System subcontractor should get the construction drawing approved by OWNER/BHEL before execution of the work.

m) The type of coating and operating temperature of each Tank should be taken into consideration for all detail-engineering calculations.

n) Wherever specific guidelines are not furnished for cathode structure current density or separation distance of anode from cathode structure and spacing between consecutive anodes, a current density shall be considered for coated piping: 3.0 mA/m². For Tank bottom plate, Mounded bullets and UG Vessels: 20.0 mA/m² and for bare cathode/incidental structure 25mA/m².

o) If operating temperatures of U/g pipeline or mounded vessels exceed 30 deg.C, protective current density shall be corrected @ 0.5mA/m2/deg.C up to a temperature of 60 deg.C.

p) Classified type local AJB/CJB need to be provided near the rim of each vessel for termination anode/cathode/reference cell/measurement cable connections.
4.07 Detailed Engineering Works To be performed by CP System sub-contractor for C.P.System

a) Following detailed engineering works are to be performed by CP System sub-contractor based on scheme given and design basis for C.P.System of all structures as per the scope of work mentioned in this document:
   - List of materials/equipments to be procured from Indian market/foreign market.
   - Item wise list of vendors with their reference lists for supply of materials/equipment.
   - Calculation and Preparation of Bill of Quantities for all C.P. system materials and equipment required.

b) Bill of quantity along with detailed calculations and preparation of specifications, installation work procedures & fabrication/construction drawings for following items:
   - C.P.System power distribution board (PDB): Total quantity and connection scheme showing group of T/R units to be connected with each C.P.System PDB and connection details between owner's switch board and each C.P.System PDB.
   - T/R unit: Total quantity, Detailed circuit diagrams and their installation drawings.
   - AJB/CJB/MJB: Total quantity and connection Scheme showing how group of anodes, anode beds and vessels are to be connected with each AJB/CJB/MJB/CDB. Also fabrication drawing & schematic drawing for internal terminal arrangements and installation drawings for a typical AJB/CJB/MJB/CDB.
   - Anodes: Total nos. of Anode strings and anode string to anode lead cable joint details for entire C.P.System and their layout arrangement drawings showing no. of anode strings in each bullet. Construction drawings and work procedures for anode to cable jointing and also for installation of anode strings.

c) Design calculations showing:
   - Cables: Total quantity of cables and their layout drawing for each C.P. Station as well as for entire C.P.System for +ve header cables, -ve header cables, anode lead cables, earthing cables, drainage cables, power supply cables and multi-core monitoring cables.
   - Cable to Tank/pipe joint: Total quantity of joints and details of a typical joint.
   - T/R unit wise C.P.System layout drawing showing how each T/R unit is connected with group of anode strings/vessels through AJB/CJB/MJB/CDB.
   - Test points: All reference cells and anode strings should be marked in a single layout drawing.
   - Overall C.P.System layout drawing including all test points, anodes, anode beds, AJB, CJB, MJB, CDB, cable routes on a plot plan. All C.P. System materials/equipment shall be marked properly for easy identification on all appropriate drawings as well as on site.
   - Preparation of testing & commissioning procedure for C.P.System.
   - Preparation of construction drawings with soft copies before starting of installation/procurement work. Preparation of Soft & hard copies of as built drawings after completion of C.P.System work, shall also be furnished.
   - Quantified list of the major construction equipment, tools, tackles etc. including Diesel engine pump set for dewatering at cable/pipe trench the BIDDER proposes to use for execution of the work.
   - Details & list of vehicles proposed to be used by the CP SYSTEM SUBCONTRACTOR during the entire construction & commissioning period for transportation of material, equipments, as well as movement of personnel within the plant area.
   - Bar chart giving details how BIDDER plans to execute the work within the specified time schedule.
   - Quality Assurance Plans/Procedure

d) The CP SYSTEM SUB-CONTRACTOR shall establish document and maintain an effective Quality Assurance system as outlined in recognized codes etc. and Quality Assurance Plans
included in Specifications etc. to ensure that the work is performed in a planned, systematic manner to the best quality standards and properly documented to provide confidence that materials supplied and/or work executed and services performed by him conform to the applicable specifications and all the requirements of contract document and work executed by him shall perform satisfactorily over the entire period of its life. The Quality Assurance Systems Plans/Procedures of the CP SYSTEM SUBCONTRACTOR shall generally cover the following aspects/details, which shall be furnished by BIDDER along with, his detail-engineering package.

- A Quality Assurance Organogram with curriculum vitae of key personnel responsible for the Quality Assurance at site.
- Complete details pertaining to the responsibility authority and accountability of the Quality Assurance Organization of the CP SYSTEM SUB-CONTRACTOR at site.
- Equipments, material, Erection, Installation, Testing and commissioning control plans for quality testing/inspection etc.
- Quality Control of processes such as Thermit welding, anode to cable jointing etc.
- Control Procedures/Plans for calibration and safe up-keep of instruments, gauges and similar testing equipments etc.
- Quality audit & Maintenance/records/procedures etc.
- Other relevant details.

e) Quality Assurance System Plans/Procedures of the CP SYSTEM SUB-CONTRACTOR shall be furnished in the form of a QA manual. BIDDER shall be required to provide explanation pertaining to the details furnished by him in accordance with provisions contained in this clause and any further details, as sought for by OWNER/BHEL. In addition, all the Quality Assurance Programs/Plans as per specifications enclosed with the Contract shall be fully complied with by the CP System sub-contractor.

- Precautionary measures to be taken to prevent fire hazard during Thermit welding and Pin Brazing of vessel for the purpose of cable to vessel joint as well as during installation, operation & maintenance of C.P.System.
- All other information as required in individual job specifications shall be furnished by CP SYSTEM SUB-CONTRACTOR in his detail-engineering package.

4.08 All erection and commissioning activities are included in vendor’s scope. Vendor’s technical personnel of suitable qualification and experience and in sufficient numbers shall be deputed to project site for soil resistivity survey and for 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.

4.09 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.

4.10 Vendor shall select the make of components of cathodic protection system from the list of sub vendors attached with technical specification. However, names of the sub-vendors may be added or deleted from the list without intimiation to the vendor and therefore it is mandatory on the part of the vendor to take approval on the make of items during detailed engineering stage. The make of items not listed in the Annexue-IX shall be subject to BHEL/ customer approval without any cost/ delivery implication to BHEL. The list of sub-vendors equipment/components shall be subject to BHEL/ customer approval.

4.11 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.
4.12 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.

4.11 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.

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

4.13 Vendor shall be responsible for 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.

4.14 All instruments and consumables required during erection/ pre-commissioning, performance testing and monitoring shall be arranged by the vendor.

4.15 Support pipes/ structures for junction boxes etc. shall be part of scope of supply.

4.16 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.

4.13 Terminal points :BHEL shall provide 2 nos. (1working + 1 standby) 240 V , single phase, 50 Hz AC power supply uncabled feeder modules at LT panels/ AC distribution boards located in various locations. 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

5.1.0 FOR IMPRESSED CURRENT CATHODIC PROTECTION (ICCP) SYSTEM

(i) 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).

(ii) The cathodic protection system will be sized in order to guarantee, at each point of same system, the minimum structure-to-soil potential value of (-) 0.95 V versus Cu/CuSO₄ half cell reference electrode.

(iii) The maximum negative potential value allowable at the drainage point will be (-) 1.2V (as per BS7361/ 1991 - Section 2, Table 1).

(iv) 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.

(v) 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.
(vi) Design life for the ICCP system shall be minimum 30 years.

(vii) At horizontal crossings the pipeline protection current density applicable for marshy area shall be considered.

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

5.2.0 FOR SACRIFICIAL ANODE CATHODIC PROTECTION (SACP) SYSTEM

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

b. 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).

c. Overall design Pipeline coating efficiency shall be considered as not more than 70% through out the design pipeline of 10 years for design of CP system.

d. The design current protection density shall not be less than (i) 0.2 mA/Sqm for the pipeline surrounded by soil of resistivity more than 100 ohm-m (ii) 0.3 mA/Sqm for the pipeline surrounded by soil of resistivity of 10 ohm-m to 100 ohm-m and (iii) 2 mA/Sqm for the pipeline surrounded by soil of resistivity less than 10 ohm-m. Under marshy conditions the protection current density shall be 5 mA/Sqm. However, the actual current density to adopted shall be suitably increased by contrac tor based upon soil conditions, current drainage, survey details, foreign pipeline/ structures and other interference areas affecting the installation. 20% design current is to be kept as provision for redundancy.

e. At horizontal crossings the pipeline protection current density applicable for marshy area shall be considered.

f. Safety factor for current density shall be minimum 1.3 for degradation of coating.

g. Anode utilization factor shall be 0.8 (max) and 0.6 (max) for solid and ribbon anodes respectively.

h. Design life for the Sacrificial Anode CP system shall be not less than specified period.

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

j. 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.

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

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.

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.

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

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.

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

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.

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.

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.

TEST STATIONS

(i) Test stations along the pipeline ROW (Right of Way) and near storage tanks shall be provided 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.

5.10.0 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 and below storage tanks.

iii) High purity copper/ copper sulphate 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) Suitable provisions shall be provided to insert reference electrodes below storage tanks for periodic monitoring of cathodic protection system performance.

vii) 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 protected structure-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 Cl 6.02 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 detects 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 fulfil 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 The successful vendor shall submit the quality & inspection plans of all equipments during contract stage and the same shall be subject to BHEL/ customer approval without any cost/ delivery implication.

8.3 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.

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

8.6 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 perform 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 perform 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.

Checking : Visual inspection, comparison with drawings and specifications.

Inspection : Detailed physical inspection and if necessary, by taking stage wise inspection of component parts.

Testing : Simultaneous tests and trial runs of entire equipment to determine its operational fitness.

9.02 Proforma for testing

a) Transformer Rectifier Unit
   - Location/ Station
   - Type, Size & Sl. No.
   - Rating
   - Insulation resistance primary to earth,
     Secondary to earth, primary to secondary
- Polarity check
- Testing of oil (if any)
- Check neutral connection
- Equipment Earthing
- Operation of tap changer
- Rectifier continuity & diodes polarity.

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 electrodes
- Earthing resistance of earthing net work
- Earthing conductor (Type & Size)
- Earthing electrodes shall be inspected before they are installed

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/ storage tanks 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 electrolyte 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.
14. Connection schemes for all applicable type of test stations and their schedules.
15. Fabrication and installation details of test stations.
16. Fabrication and installation details of anode and cathode junction boxes, schedules and connection schemes.
17. Interconnection, sectionalisation, isolation schemes for all structures to be protected and those to be isolated but to be checked out for interaction.
18. Power supply arrangement for each T/R set.
20. Procedures for testing during installation, commissioning and monitoring of (after installation) complete CP system & each equipment.
21. Design and drawings that may be required for mitigation purposes.
22. Complete CP system layout drawings for each CP station.
23. Cable to pipe joint arrangement using thermite welding.
24. Material test certificate for the materials purchased by the vendor along with copy of manuals.
25. Inspection and test certificates for items fabricated and erected.
27. Final check list and completion report.
29. Monitoring formats.
30. Monitoring schedules.
31. List of E&C Spares.
32. Billing break-up

Note: The list of deliverables shall be finalised during kick-off meeting at contract stage.
### SPECIFICATION FOR C.P. SYSTEM EQUIPMENT AND MATERIALS

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1.00 Specifications and Testing of Transformer Rectifier Units
The specifications and testing procedure for classified type TR unit (Incase required) need to be prepared by vendor for review/approval by BHEL/OWNER. The specifications and testing procedure for non classified IP-55, weather proof type transformer units are given as follows:

1.01 TRANSFORMER RECTIFIER UNITS(TR UNITS)
The Cathodic Protection Transformer Rectifier unit consists of air-cooled transformer, full wave rectifier, LC circuit for filtering, metering with auto pipe to soil potential control facilities. The TR unit shall also have the facilities for manual control through stepped tapping on the secondary side of the Transformer. The TR unit shall be suitable for outdoor installation having minimum IP-55 degree of protection. Owner will provide un-cabled supply feeder in its LT panel for extending AC power supply to the AC operated transformer rectifier type CP units.
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, standard and data sheets.

1.02 CODES AND STANDARDS
In general the T/R Unit covered by this specification shall unless otherwise specified, be in line with the requirements of any of the latest applicable standard of:
a) Indian Standards Institution(ISI)
b) International Electrotechnical commission(IEC)
c) American Standards Institution(ANSI)
d) British Standards Institution(BS)
which shall include but not to the following:
i) IS: 2026 - Power transformers
ii) IS:2026(Part I)-1977 - General(first revision) with Amendments No.1 to 3)
iii) IS:2026(PartII)-1977- Temperature -rise (first revision) with Amendments No.1 and 2
iv) IS:2026(Part III)-1981 - Insulation levels and dielectric tests(Second revision) with Amendment No.1.)
v) IS:2026(Part IV-1977 - Terminal markings, tappings and connections(first revision) with Amendment No.1.)
vi) IS:3700 - Essential ratings and characteristics of Semiconductor devices.
ix) IS:3700(PartIII)-1973 - Rectifier Diodes(First revision)&IS:4400(Part III)-1968 (Reaffirmed 1988)
x) IS:3700(PartIV)-1968 - Low power small signal transistors& IS:4400 (Part IV) 1981(Reaffirmed 1988)
xi) IS:3700(Part V)-1968 - Power transistors(Reaffirmed1988)

Wherever the requirements in this specification are in conflict with any of the above standards, the requirements under this specification shall be binding.

1.03 TRANSFORMER
Lighting transformer shall be dry type, natural air cooled and suitable for mounting inside the lighting distribution board. Transformer shall be non-encapsulated type, unless specified otherwise in Data Sheet. Transformer winding insulation shall be class “F” or better. Winding shall be of copper material and maximum winding temperature at full load and under site conditions shall not exceed 120 °C.. Transformer full load efficiency will not be less than 95%.
1.04 RECTIFYING ELEMENTS
The power rectification shall be done by Silicon diodes mounted on heat sinks of sufficient size to prevent the diode case temperature from exceeding 100°C at ambient temperature as per data sheet. The peak inverse voltage rating and current ratings of the diodes shall be as per data sheet. The diodes shall be connected in Bridge circuitry for full wave rectification. Each diode in the bridge circuit shall be protected by a HRC fuse.

1.05 A.C. INPUT
The transformer rectifier units shall be designed to operate on 240 volts (+/-10%) AC single phase, 50 Hz power supply. Inrush current limiting reactor of suitable rating to be provided at input line of the main transformer to avoid possibility of abnormal tripping of MCB while closing circuit using MCB.

1.06 D.C. OUTPUT
The transformer rectifier shall be designed to operate continuously at 110% rated output current and 110% rated output voltage at input supply voltage 240v (+/-10%) without exceeding specified hot spot temperature limit and without damaging any components.

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

a) 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.

b) 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.

(i) CONSTANT CURRENT AND VOLTAGE CONTROL (AVCC MODE)
Constant current control feature shall be achieved by automatically adjusting T/R unit output voltage between 0 to 110% rated voltage through close loop control using T/R unit output current as feed back taken from the shunt inside the T/R unit so that T/R unit output current of any value between 0 to 110% rated current does not vary more than +1.0A of set value when there is a change input supply voltage of +10% or change in load resistance over a specified range decided by the ratio of output voltage & current rating of the T/R unit.

(ii) CONSTANT PIPE TO SOIL POTENTIAL CONTROL
Constant Pipe to soil potential (PSP) control feature shall be achieved by automatically adjusting T/R unit output voltage between 0 to 110% rated voltage through close loop control using PSP as feedback taken from external reference cell, to cause change in output current of T/R unit so that PSP as measured by external reference cell always remains constant and does not vary more than +0.04% of the set potential. For feedback PSP reference, 2 nos. Cu/CuSO4 ref. cells to be used one operating and other standby to be selected manually with the help of a selector switch. Continuously adjustable potentiometer to be used for setting T/R unit output current/PSP. Silicon controlled...
Rectifiers (SCR's) shall be used in the Primary Circuit of main Transformer for close loop control of the output voltage in automode. The SCR's of the transformer rectifiers will be controlled by commands from electronic circuit cards. These cards shall be the plug-in type Printed Circuit Board (PCB) mounted on the front panel of the rectifier for easy field replacement. The printed circuit board contact pads will be chromium plated to provide easy conduction and to eliminate contact corrosion. Complete printed circuit boards will be sealed with a circuit card sealant to prevent atmospheric corrosion and fungus contamination. Circuit elements in the control cards shall be derated properly and proper heat dissipation arrangements shall be made in the PCB so that they function properly for full load operation of T/R unit at ambient temperature as per data sheet.

1.08 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.

1.09 Separate-Drainage Control

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

1.10 DC OUTPUT RIPPLE

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

1.11 INPUT OVER LOAD PROTECTION

(a) 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.

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

(c) 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.

1.12 OUTPUT OVER LOAD PROTECTION

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

(b) 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 fine switch shall give limit of 0, 3A, 6A, 9A, 12A, 15A.

(c) The limit of the two switches shall be algebraically additive and shall give 25 steps of 3A each.
The maximum current limit can be set by operator at any desired valve in 3 steps and in any circumstances even in case of short circuit the output current should not exceed the maximum set current limit.

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.

**1.13 VOLTAGE SURGE PROTECTION**

(a) 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.

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

**1.14 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.

**1.15 INPUT AND OUTPUT TERMINALS**

(a) 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.

(b) 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.

**1.16 METERS**

(a) 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.

(b) 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.

(c) 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% temperature change.

(d) All ammeters and voltmeters shall be provided with separate fuse and toggle switch.

**1.17 ANNUNCIATION**

**1.18**
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.

1.19 ENCLOSURES

a) 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.

b) 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.

c) 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.

d) After fabrication the entire enclosure shall be sand blasted to Sa 2 1/2 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.

1.20 ENCLOSURE EARTHING

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.

The earth connection points shall be protected against corrosion. It shall not be necessary to scrape the paint away in order to make an effective earthing connection. Provision shall also be made adjacent to each gland plate for cable gland earthing connection.

1.21 CABLE TERMINATIONS

a) Cable glanding and terminating facilities and terminals shall be suitable for the specified cable type and conductor size. Consideration and provision shall be taken by the manufacturer on the equipment design for the use of cables with aluminium conductors.

b) Cable glands & cable lugs shall be in the scope of supply for CP system installation CP System sub-contractor.

c) Terminal blocks shall be arranged and positioned to afford easy access for carrying out external cable termination, testing, inspection and maintenance. There shall be ample clear space allowed between the terminal block and the gland plate for the spreading and termination of external conductors.
d) All terminal blocks shall be shrouded or provided with transparent covers. Pinch screw type terminals are not acceptable.
e) Three positive and three negative post type D.C. output terminals shall be provided for the T/R Unit. Each post shall be fitted with double nuts and washers.
f) Terminals for different voltages shall be separated by partitions.
g) A terminal box or chamber with undrilled gland plate or entry panel of sufficient dimensions to terminate the specified incoming and outgoing cables shall be provided.
h) Direction of cable entry shall be from below.
i) Termination of single core cables shall be through a non-magnetic metal panel or gland plate and provision made for bonding and earthing any armour and/or concentric ground conductors.
j) Cable terminal arrangements for power and control cables may be integrated provided that a barrier separates the two.
k) Auxiliary wiring shall have copper conductors of the manufacturer's standard sizing (subject to Buyer's approval).
l) Suitable terminals for two nos. ref. cell cables, one no. measurement cables and a selector switch for permanent ref. cell to be provided for T/R unit panel for connection to PSP meter. Wiring shall be crimped using self-insulated compression type terminal blocks which shall be suitably identified. Conductors shall be fitted with sleeve ferrules bearing the same identification as the terminal to which they are connected. Minimum conductor size shall be 1.0mm² (current density shall not be more than 3A/mm² for copper conductor).

1.22 NAME PLATE

A permanently stamped metal plate with the following information shall be fixed to the outside of the case:

A Manufacturer’s name
B Year of manufacture
C AC input voltage and current rating
D AC frequency
E Phase
F Maximum output DC Volts and Amps rating
G Weight in Kg of T/R unit
H Model number
I Serial number

1.23 TESTING OF T/R UNITS

All T/R units shall be tested by CP System sub-contractor and inspected by BHEL/Owner before despatch, testing shall be conducted in accordance with codes and standards enclosed in this document, as per routine tests done by manufacturer and additional tests as mentioned below:

a) Efficiency test of Transformer Rectifier Assembly at 25%, 50%, 75% and 100% rated output current both in Auto and manual mode of operation. Efficiency test of Transformer alone after isolating rectifier at 100% rated output current.

b) No load output voltage test in Manual mode for each voltage setting using coarse and fine tap switches at rated input voltage of 240V AC.

c) Output voltage and current test in Manual mode for each voltage setting using coarse and fine tap switches for the following conditions.

(i) Input voltage 240V AC, load resistance 1.65ohm for 50A T/R & 1.1 ohm for 75A T/R
(ii) Input voltage 253 VAC, load resistance 1.65ohm for 50A T/R & 1.1ohm for 75A T/R
(iii) Input voltage 207 VAC, load resistance 1.65ohm for 50A T/R & 1.1 ohm for 75A T/R.

d) Output voltage test at rated output current setting in Auto mode for the following conditions.

(i) Input voltage 240VAC, load resistance : 1.65ohm for 50A T/R & 1.1 ohm for 75A T/R
(ii) Input voltage 253 VAC, load resistance : 1.65ohm for 50A T/R & 1.1 ohm for 75A T/R
(iii) Input voltage 253 VAC, load resistance 0 ohm (short circuit across +ve and -ve terminal of T/R unit). Set back up control 75A & 50A for 75A & 50A T/R unit respectively.

(iv) Input voltage 207 VAC, load resistance: 1.65 ohm for 50A T/R & 1.1 ohm for 75A T/R. Output current and voltage shall be recorded for each of above conditions (i) to (iv).

e) Heat run test for max. temp rise to be conducted for main transformer, Auto transformer, filter choke, Diodes and SCR's, at 50A output current for 50A T/R Unit & 75A current for 75A T/R unit for 48 to 72 hours continuous operation. Number of T/R units to be considered for Heat run tests and actual duration for which test to be conducted up to 72 hours (max.) shall be decided by BHEL and owner. Thermocouple instrument shall be used for measurement of temperature. The sensors shall be clamped at different locations inside the closed T/R unit cubical and the cable of the sensors shall be connected to temperature indicator through a selector switch outside the T/R unit cubical during heat run test.

f) Insulation resistance test using 500V megger for Auto transformer and Main transformer between primary and secondary, primary and earth, secondary and earth.

g) Dielectric strength test using 2KV for 1 min. duration for Auto transformer, main transformer between Primary and secondary, primary and earth, secondary and earth.

h) Polarity test in Auto and manual mode of operation of T/R unit.

i) Calibration test for all Ammeters and volt meters.

j) Auto mode over load protection test:

k) Set back up control and increase current from zero to max. Possible using main Auto control for T/R Unit having constant current control.

In case of Auto PSP control T/R unit ref. feedback signal to be varied from min. to max. set potential of T/R unit using battery & rheostat in place of ref. half cell signal, current during the test should not exceed more than set current in both cases.

l) Constant Current Test

(i) D.C Current Regulation against variation in AC Input

(ii) Put the unit in constant current mode and set the output current at 75 A by the help of current setting potentiometer and observe the variation in, if any, of output current with variation of AC input voltage at the steps keeping the output load constant: 216V, 240 V, 264 V.

(iii) D.C Current Regulation against variation in Load Voltage

(iv) Keeping the AC input voltage at 240 V constant, set the output D.C current at rated current and observe for any variation of DC current with variation of output load voltage at three different values ensuring that at each output load voltage, taking care voltage limit set value is not exceeded. Repeat the above at 75%, 50% and finally at 50% set output current.

m) Constant voltage test for control circuitry. Supply voltage of T/R unit to be applied 240V 184V and 276V. For each input supply voltage the reference voltage, +ve DC and -ve DC voltages of Auto mode control circuit to be checked whether they are constant.

n) D.C Voltage Regulation against variation in Load Current

Keeping the AC input Voltage at 220 V constant, set the output D.C voltage at 48 V and observe for any variation of D.C Voltage with variation of output load current at three different values ensuring that each output load current, current limit set value is not exceeded. Repeat the above at 24 V and finally at 12 V set output Voltage.

o) Ripple factor test

T/R unit shall be operated at full load both in Auto and Manual mode. In each case ripple voltage to be checked on a cathode ray oscilloscope (CRO). Peak to Peak ripple wave from shall be limited within 7.05 volt in CRO screen for 50 volt TR unit & 10.575 volt for 75 volt TR unit.

p) Annunciation check:

Annunciations check to be done for power on, manual mode operation and auto mode operation.

q) Auto mode constant PSP operation test:
Connect one battery with variable rheostat in place of reference cell feedback signal and conduct the following test:
(i) Make both T/R unit set potential & feedback signal from battery 1.0V, Switch on T/R unit & note T/R output current. Increase feedback signal from 1.0V to 1.5V and again bring back to 1.0V. Note change in the T/R output current.
(ii) Conduct similar test as item (i) above with decrease of feedback signed from 1.0V to 0.5V and again back to 1.0V. Note change in the T/R output current.

r) Power consumption test for each:

T/R Unit:
Forward voltage drop of each diode at T/R unit rated output current:
(i) D1=
(ii) D2=
(iii) D3=
(iv) D4=
Power consumption:
(i) D1=
(ii) D2=
(iii) D3=
(iv) D4=
Voltage drop and power consumption should not be more than specified value mentioned in diode manufacturer’s catalogue.

s) Power consumption test for filter choke:
Voltage drop across choke at 75A T/R Unit output current =
Power consumption of choke at 75A T/R unit output current =

1.24 DRAWINGS/ DOCUMENTS

a. Fabrication drawings and data sheet of T/R unit with all dimensions, ratings and weight in final issue, including installation/ foundation arrangement details.
b. Front view and typical section of T/R unit panel with arrangement of equipment, control, protection and metering.
c. Data sheet of all accessories and circuit element of T/R unit including ratings.
d. Schematic and wiring diagram of T/R unit circuitry including Auto/ Manual Mode of control.
e. Fabrication drawings, connection scheme details and data sheet of Distribution Board with all dimensions, rating and weights in final issue including mounting details.
2.00 SPECIFICATION FOR MIXED METAL OXIDE COATED TITANIUM TUBULAR ANODE FOR C.P. SYSTEM

2.01 Mixed Metal Oxide Coated Titanium single tubular anodes shall be of BHEL/owner approved standard manufacturer, for use in impressed current Cathodic Protection system. This specification covers the requirements for the design, manufacture and testing of anodes suitable for underground application.

2.02 Anode (preferably LIDA type) and backfill material and construction shall be in accordance with the standards listed in the specification, and shall be in proven use.

2.03 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.

2.04 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.

2.05 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.

2.06 Anode-bed plot limited upto 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.

2.07 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.

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

2.09 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.

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

2.11 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.

2.12 Sizing of ground bed at each CP station shall be such that its total resistance to remote earth does not exceed 1.0 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.
2.13 The boundary of the anode bed should be clearly marked with the help of permanent boundary of fencing.

2.14 Mixed Metal oxide coated Titanium tube anodes shall be dimensionally stable and will be supplied with anode lead cable connected to it.

2.15 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 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 least 12 inches on both above and below connector.

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

2.16 Anode to cable jointing and insulation shall be done by anode manufacturer at his shop.

2.17 Anode lead cable conductor shall be crimped with tubular anode at the center of anode or at the ends and shall be sealed to prevent ingress of water at the joint. Fabrication details of the joint including sealing arrangement and test procedure of the joint shall be furnished by vendor or BHEL's approval before making the joints.

2.18 Manufacturers/ supplier shall furnish detailed dimensioned fabrication drawing of anode as well as details of anode to cable connection and its insulation sealing to OWNER/PMC for approval. Manufacture of anodes shall be commenced after obtaining approval and inspection of a prototype joint by BHEL/owner at anode manufacturer's works. Anode Manufacturer shall furnish following information for BHEL/owner approval before commencement of Anode to cable joint.

- Name of Manufacturer of joint sealing material along with Physical & Chemical Properties.
- Type and make of Heat shrink cap along with its grade and properties.
- Procedure for making the joint

2.19 Following prototype and routine tests are to be conducted by anode manufacturer. Anodes with cables shall be delivered to site only after OWNER/PMC's approval of the test results which are to be furnished by anode manufacturer for each anode. Detailed procedure for conducting the following tests shall be furnished by manufacturer for BHEL/owner approval before commencing tests.

(a) Dimensional check (Routine tests): Dimension & weight of all anodes to be checked & recorded. Negative tolerance will not be accepted.
(b) Anode Lead cables (Routine tests): Routine & type test certificates of cable manufacturer to be furnished for anode lead cable as per IEC 502-1983 or relevant IS code. Cable length and identification tag to be verified by measurement.

(c) Anode to Cable joint test (Routine tests): Each anode to cable joint shall be tested for its electrical contact resistance & its value in ohms shall be recorded.

(d) Prototype Test: First anode to cable joint shall be subjected to accelerated aging test & destructive test to determine pull out strength of cable to anode joint as well as effectiveness of the joint insulation.

(e) The vendor shall furnish spectrographic analysis of anodes from each heat.

(f) 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.

(g) 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.

(h) 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.

(i) 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.

(j) 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.
3.00 SPECIFICATION FOR CONDUCTIVE POLYMER ANODE

3.01 Conductive Polymer anodes shall be for use in impressed current cathodic protection system of tank bottom plates. This specification covers the requirements for the design, manufacture and testing of anodes suitable for application in sand pad under tank bottom plates.

3.02 Conductive Polymer anodes shall be dimensionally stable and shall consist of parallelly installed anode strings connected together. Connection of anode lead cable to the Anode string assembly shall be carried out at site.

3.03 Anode internal header cable and anode lead cable in between each anode string and AJB shall be PVC/XLPE insulated, 7 strands, 10mm² stranded copper conductor, single core, un-armoured, type.

3.04 Anode to Lead cable jointing and insulation shall be done by using straight through jointing kit which is to be provided by anode manufacturer. Anode to Lead cable jointing and insulation shall be done at manufacturer’s work shop or at field by a trained cable jointer.

3.05 Manufacturers/ supplier shall furnish detailed dimensioned fabrication drawing of anode string assembly as well as details of Anode string to Anode Lead Cable connection and its insulation sealing to OWNER/ BHEL for approval. Manufacture of anodes shall be commenced after obtaining approval and inspection of a prototype joint by OWNER/ BHEL at anode manufacturer's works.

3.06 Anode Manufacturer shall furnish following information for OWNER/ PMC approval before commencement of String anode to Anode Lead Cable joint:
   - Type and make of Heat shrink cap along with its grade and properties.
   - Procedure for making the joint

3.07 Following prototype and routine tests are to be conducted by anode manufacturer. Anodes shall be delivered to site only after OWNER/PMC’s approval of the test results which are to furnished by anode manufacturer for each anode. Detailed procedure for conducting the following tests shall be furnished by manufacturer for OWNER/PMC’s approval before commencing tests.
   i) Dimensional check (Routine tests): Dimension & weight of all string anodes to be checked & recorded. Negative tolerance will not be accepted.
   ii) Anode Lead cables (Routine tests): Routine & type test certificates of cable manufacturer to be furnished for anode lead cable as per IEC 502-1983 or relevant IS code. Cable length and identification tag to be verified by measurement.
   iii) String anode to Anode Lead Cable joint test (Routine tests): Each anode to cable joint shall be tested for its electrical contact resistance & its value in ohms shall be recorded.
   iv) Prototype Test: First String anode to Anode Lead Cable joint shall be subjected to accelerated aging test & destructive test to determine pull out strength of cable to anode joint as well as effectiveness of the joint insulation.
4.00 SPECIFICATION FOR MIXED METAL OXIDE WIRE ANODE

4.01 Factory coke backfilled fabric jacketed Mixed Metal Oxide wire anodes shall be a standard product of the manufacturer regularly engaged in the production of such anodes for use in impressed current Cathodic Protection system. The make /model of MMO wire anode to be supplied shall be either “MATCOR Make SPL™-FBR-16” or Covalence/Tyco/ Berry Plastics (USA) Make Make (Anodflex-3020).

4.02 Mixed Metal oxide anodes shall be dimensionally stable. Each wire anode shall be supplied with anode lead cable piggy back connected to it i.e there will be connection between the Primary anode and the internal header cable at a every 3m (max) distance. The connection shall be multi-step and water proof.

4.03 Anode internal header cable and anode lead cable in between each anode string and AJB shall be KYNAR/HALAR insulated, 7 strands, 10mm2 stranded copper conductor, single core, unarmoured, with a double insulation system. The primary insulation shall be 0.04 inch thick cross-linked polyvinylidene floride (PVDF) 1100 Volt grade. The secondary insulation shall be 0.065 inch thick high molecular weight polyethelene (HMWPE) sheathing jacket over the primary insulation. Jointing of anode lead cable with internal anode header cable and its insulation shall be done by using standard jointing kit which is to be provided by anode manufacturer. However, preference will be given for direct termination of the anode header cable to AJB without any joint in between with internal anode header cable and anode lead cable. Wire Anode to anode header cable jointing incase unavoidable, shall be done at factory or site by a trained cable jointer.

4.04 Manufacturers/ supplier shall furnish detailed dimensioned fabrication drawing of anode string assembly as well as details of Anode string to Anode Lead Cable connection and its insulation sealing to OWNER/ BHEL for approval. Manufacture of anodes shall be commenced after obtaining approval and inspection of a prototype joint by OWNER/ BHEL at anode manufacturer's works.

4.05 Anode Manufacturer shall furnish following information for OWNER/ PMC approval before commencement of String anode to Anode Lead Cable joint.
   - Type and make of Heat shrink cap along with its grade and properties.
   - Procedure for making the joint

4.06 Following prototype and routine tests are to be conducted by anode manufacturer. Anodes shall be delivered to site only after OWNER/PMC’s approval of the test results which are to furnished by anode manufacturer for each anode. Detailed procedure for conducting the following tests shall be furnished by manufacturer for OWNER/PMC’s approval before commencing tests.
   v) Dimensional check (Routine tests): Dimension & weight of all string anodes to be checked & recorded. Negative tolerance will not be accepted.
   vi) Anode Lead cables (Routine tests): Routine & type test certificates of cable manufacturer to be furnished for anode lead cable as per IEC 502-1983 or relevant IS code. Cable length and identification tag to be verified by measurement.
   vii) String anode to Anode Lead Cable joint test (Routine tests): Each anode to cable joint shall be tested for its electrical contact resistance & its value in ohms shall be recorded.
   viii) Prototype Test: First String anode to Anode Lead Cable joint shall be subjected to accelerated aging test & destructive test to determine pull out strength of cable to anode joint as well as effectiveness of the joint insulation.

5.00 SPECIFICATION FOR CALCINED PETROLEUM COKE BREEZE

5.01 Calcined Petroleum Coke Breeze shall conform to the following specifications as per IS:8502-1977, Grade A,
A Chemical Composition:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (on Dry Basis)</td>
<td>0.1 (% by mass)</td>
</tr>
<tr>
<td>Fixed Carbon</td>
<td>99.0 (% by mass)</td>
</tr>
</tbody>
</table>

B Bulk density 800 Kg/m3 to 1200 Kg/m3

C Real density 2.03 gm/cc

D Particle Size 1.00mm(max.), Dust free

E Resistivity 0.1 ohm cm. at 150 PSI.

5.02 Test Certificates
Test Certificate shall be furnished for the following:
- a) Make of coke breeze
- b) Batch no.
- c) Chemical composition
- d) Bulk density and Real density
- e) Particle size analysis
- f) Resistivity( ohm-Cm.) at 150 psi compaction

Any delivery effected without prior approval of test certificate by BHEL/owner will be at suppliers risk & cost.

5.03 Above mentioned specification for coke breeze shall be considered for MMO tubular anodes incase required for supplementary design, the coke breeze to be considered for MMO wire anode may be of make as per the anode manufacturer's choice meeting the requirements of the specifications mentioned above.
6.00 SPECIFICATIONS FOR PERMANENT REFERENCE HALF CELL

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

6.02 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).

6.03 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.

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

6.05 Minimum three (3) nos. permanent reference electrodes will be required at each drain point one at either side of pipe for each transformer rectifier unit. This 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.

6.06 Each reference shall be supplied in cotton bag of chemical backfill having overall size 8" dia x 16" long and complete with 25 M (minimum) cable as per specification. However, CP System sub-contractor to measure the actual length of measurement cable required at site during detailed engineering stage and cut the required length from cable drum so as to avoid cable-to-cable joint.

6.07 COPPER/ COPPER SULPHATE REFERENCE ELECTRODE

(a) 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.

(b) 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.
6.08 SILVER/ SILVER CHLORIDE REFERENCE ELECTRODES

(a) 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.

(b) 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.
7.00 SPECIFICATION FOR CABLES

7.01 This specification covers requirements for type, rating, manufacture and testing of the cables to be used for impressed current type cathodic protection system.

7.02 CODES AND STANDARDS
In general the cables covered by this specification shall unless otherwise specified be in the line with the requirements of any of the latest applicable standard of:

a) IS: 7098(Part I) -1988
b) IS: 1554
c) IS: 3961(Part IV)-1968
d) IS: 3961(Part II)-1967

Wherever the requirements in this specification are in conflict with any of the above standard, the requirements under this specification shall be binding.

7.03 ANODE LEAD CABLE
Anode internal header cable and anode lead cable in between each anode string and AJB shall be PVC/ XLPE insulated, 7 strands, 10mm² stranded copper conductors, single core, unarmoured.

7.04 +VE, -VE HEADER CABLE
+ve header and -ve header cables shall be of cross section as required, stranded copper conductor, single core, aluminum wire armoured, PVC insulated and PVC sheathed 1100V grade cable.

7.05 DRAINAGE CABLE
Drainage cables shall be 50mm², stranded aluminium conductor, single core, aluminum wire armoured, PVC insulated and sheathed 1100V grade cable.

7.06 POWER SUPPLY CABLE(Between PDB & T/R Unit)
Power supply cable between Power source or C.P. System DB and T/R unit shall be 25mm², stranded aluminum/copper conductor, 3-core, Aluminum wire armoured, PVC insulated and sheathed 1100V grade cable.

7.07 POWER SUPPLY CABLE (between Power Source & PDB).
Power supply cable between Power source & C.P. System PDB shall be 50mm², stranded Aluminum conductor, 4-core, Aluminum wire armoured, PVC insulated & sheathed 1100 V grade cable.

7.08 EARTHING CABLE
Earthing cable shall be 35mm2, stranded Aluminum conductor, 1-core, unarmoured, PVC insulated and sheathed 1100V grade cable.

7.09 MEASUREMENT CABLE AND PERMANENT REFERENCE CELL CABLE BETWEEN TANK/VESSEL/BULLET AND CJB CUM TEST STATION
The measurement cable and permanent reference cell cable shall be 4mm2, stranded copper conductor, single core, PVC insulated and sheathed, 1100V grade aluminum wire armoured and screened cable.

7.10 MEASUREMENT CABLE AND PERMANENT REFERENCE CELL CABLE BETWEEN CJB CUM TEST STATION AND MJB
The measurement cable and permanent reference cell cable shall be 2.5mm2, solid copper conductor, 10 core, PVC insulated and sheathed, 1100V grade aluminum wire armoured and screened cable.
7.11 MEASUREMENT CABLE AND PERMANENT REFERENCE CELL CABLE BETWEEN MJB AND TR UNIT
The measurement cable and permanent reference cell cable shall be 2.5mm², solid copper conductor, 10 core, PVC insulated and sheathed, 1100V grade aluminum wire armoured and screened cable.

7.12 REFERENCE CELL / MEASUREMENT CABLE BETWEEN MJB & RTU/PLC
Instrumentation cable, 2.5mm², 20-core, stranded copper conductor, PE/PVC insulated and PVC sheathed, screened and armoured cable, PE/PVC insulation of each core shall be Numbered or colour coded for easy identification of each core.

7.13 REFERENCE CELL / MEASUREMENT CABLE BETWEEN TRU & RTU/PLC
Instrumentation cable, 2.5mm², 24-core, stranded copper conductor, PE/PVC insulated and PVC sheathed, screened and armoured cable, PE/PVC insulation of each core shall be Numbered or colour coded for easy identification of each core.

7.14 TELEPHONE CABLE BETWEEN RTU/ CENTRAL MONITORING PC TO LOCAL TELEPHONE EXCHANGE, LOCAL TELEPHONE EXCHANGE TO MAIN TELEPHONE EXCHANGE.
Telephone cable, 0.5mm², 5-Pair, each pair twisted and Laid, Numbered or colour coded, solid copper conductor, PE insulated and sheathed, Jelly filled provided with polyester tape over it, screened with Poly Aluminium tape of 0.3mm and armoured with one layer of GI wire cable. In case other than telephone communication is considered, contractors need to design, supply and install the same after taking BHEL/OWNER’s approval for the same.

7.15 POWER SUPPLY CABLE BETWEEN PDB TO LOCAL TELEPHONE EXCHANGE & PDB TO RTU/PLC FOR CENTRAL MONITORING
Power supply cable between PDB to local TELEPHONE EXCHANGE & PDB to RTU for central monitoring shall be 16mm², stranded Aluminum conductor, 3-core, aluminium wire armoured, PVC insulated and sheathed 1100V grade cable.

7.16 CABLE DRUMS
All cables to be supplied in wooden drums. Cable lengths in each cable drum shall be 500m (min.) where ever cable lengths are more than 500m.

7.17 INSPECTION
All cables along with manufacturer's test certificate as per IS standards shall be inspected by OWNER/BHEL at the vendor's shop before despatch. Minimum 15 days advance notice to be furnished by vendor for this purpose. In case of any doubt OWNER/BHEL may insist vendor to conduct the tests as per IS standards in presence of OWNER/BHEL at some third party reputed laboratory approved by OWNER/BHEL at no extra cost.

7.18 CABLE IDENTIFICATION
(a) For easy identification of cable, the oversheath of the cable should have yellow colour and "C.P. SYSTEM CABLES" should be printed using black colour at one meter interval throughout the length of the cable.
(b) All cables will be identified and labelled at terminal blocks of test station and transformer rectifier.

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

Structure to protect : Green
<table>
<thead>
<tr>
<th>Component</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<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>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</td>
</tr>
<tr>
<td>Reference cell</td>
<td>White</td>
</tr>
<tr>
<td>Half cell</td>
<td>Yellow</td>
</tr>
<tr>
<td>Structure</td>
<td>Yellow/Green</td>
</tr>
</tbody>
</table>
8.0 SPECIFICATION FOR THERMID WELDING

8.01 Thermit 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.

8.02 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.

8.03 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).

8.04 Each thermit weld connection will basically require the following equipment:
   a. Thermit weld mold.
   b. Thermit weld metal.
   c. Thermit weld cap
   d. Steel disc.
   e. Copper sleeve
   f. Flint ignitor.
   g. Mould packing.
   h. Epoxy encapsulation kit.
9.00 SPECIFICATION FOR POWER DISTRIBUTION BOARD

9.01 The Power distribution board (PDB) shall be plinth mounted outdoor type if TR Unit is installed out door and shall be installed at classified locations near a single or group of T/R Unit under a sun/rain shed. The enclosure of shall be classified type as per relevant IEC/NEC codes.

9.02 The Power distribution board (PDB) shall be composed of one no.3 phase, 4-wire 125A/63A, incoming MCCB and required nos. of 1 phase, 63A outgoing MCB. The incoming switch shall be 4-pole and outgoing switches shall be 2-pole. The MCCB and MCB shall be suitable for motor load application and shall be of BHEL/OWNER approved make.

9.03 4 Nos. of 25x5mm tinned copper busbar shall be used which should be taped by PVC tape of red, yellow and blue colours for identification of the three phases and black colour for neutral. Wiring inside PDB shall be done using 50mm2, 1-core, copper conductor, PVC insulated, unarmoured cable between TPN switch neutral and neutral bus whereas rest of the wiring shall be done by 25mm2, 1-core, copper conductor, PVC insulated unarmoured cable. All single core cables shall be used red, yellow and blue coloured for phase connections and black coloured for neutral connection.

9.04 All cables terminations shall be through Tinned copper cable lugs of matching cable size. All cable entries to the PDB panel shall be through Aluminium single compression glands. One gland for 3-phase, 4-core incoming cable connection shall be provided at left side bottom of the panel, required nos. of glands to be provided at right side bottom of the panel for outgoing cable connections for 63A PDB.

9.05 Size of the PDB Panel enclosure shall be adequate to accommodate all components easily and shall be made of 2 mm sheet steel. Two nos. hinged front shutters shall be provided. The shutters shall be screwed to the panel enclosure structure at the centre in addition it shall have lockable handles. Painting details of inside and outside surfaces of the PDB panel shall be as follows: After fabrications the entire enclosure shall be sand blasted to a SA2½ surface. An inorganic zinc primer shall then be sprayed to a total thickness of 3 mils. The finish coat shall be of polyamide cured epoxy in three coats to achieve total thickness of 15 mils. The finish coat shall be as per choice of OWNER/BHEL. CP SYSTEM SUB-CONTRACTOR shall prepare the layout/construction drawings and a prototype of PDB showing internal terminal arrangement and wiring arrangements and submit to OWNER/BHEL for approval before procurement/ installation of the same at site.
10.00 **SPECIFICATION FOR ANODE, CATHODE & MONITORING JUNCTION BOXES**

10.01 An anode lead junction box (AJB) will be provided to feed T/R Unit output current to anode strings. All anode cable tails from individual anodes shall be terminated into ‘Anode Junction Box’ and further connected to the anode bus. Anode cable coming from CP unit shall be connected to Anode bus. Anode junction box shall essentially contain anode bus, ammeter shunts of suitable rating and control resistance. All the cable tail from the individual anodes shall be connected to anode bus through current measuring shunts and variable resistance for control of anode current from each anode. At least 30% spare anode terminals complete with current measurement and control facilities and cable termination arrangement shall be provided. Depending on the size and configuration of anode- ground beds one or more anode -junction boxes shall be provided with the ground bed.

10.02 All the cable / lead wire entry to Anode Junction box shall be through double compression type water and weather proof type cable glands.

10.03 Anode junction Box shall be erected on a structure/ wall. A chain link fencing having door & locking arrangement shall be provided around the Anode junction box. Contractor shall furnish required engineering / construction drawing of the chain link fencing, Anode junction box for approval of BHEL/owner. The rate of the anode junction box should be inclusive of the foundation and chain link fencing pertaining to the anode junction box for which no separate payment shall be made. Flame proof anode junction boxes are to be used in hazardous areas inside pumping / boosting / terminal / T point / Intermediate stations whereas non-flame proof junction boxes shall be used in the remaining sites. Flameproof junction boxes shall not require any chain link fencing.

10.04 Where output of the CP power supply unit is connected to multiple pipelines/ structures a cathode junction box shall be supplied for connection of the negative drainage cable to the pipelines. The Junction box shall have a bus bar with an incoming circuit for connecting to the negative of CP power source and separate outgoing circuits for collection of negative drainage current from each of the pipelines. Terminals shall be of anti loosening type and shall be clearly identified.

10.05 Cathode junction Box for Cathodic protection shall be erected near transformer rectifier unit indoors. It shall have minimum one input (from TR unit) & minimum three outputs (for connecting to multiple structures). Each output circuit shall have variable resistor to control the required current manually.

10.06 Cathode junction box cum test station (CJB) will be required for bonding multiple structures at drain point as well as for measurement of potential for each structure. One CJB shall be provided for each structure. Drainage cable, reference cell cables and measurement cables from structure shall terminate in its respective cathode junction box cum test station. All the above-mentioned reference cell cables and measurement cables from each CJB shall be terminated into a single Monitoring junction box (MJB). Each CJB shall be connected to the negative terminal of the T/R unit through loop in loop out arrangement for return of drainage current from multiple structures to the T/R unit.

10.07 The enclosure of CJB shall be structure/wall mounted type. Shutter should be provided with closed cell neoprene sealing gaskets. The terminal board shall be of 10mm WT Phenolic laminated sheet on which all terminals and shunts are to be mounted. The terminals shall be made of cadmium plated steel or stainless steel stud nut and washers of M-10 size for termination of anode and cathode lead cables and M-4 size for termination of reference cell and measurement cables. All cable entries shall be through Aluminium double comprehension
glands. The external bolt, nuts and clamps to be used for mounting the junction box with back plate/structures shall be MS electro-galvanised or Cadmium plated.

10.08 Monitoring junction boxes (MJB) will be installed near the T/R Unit and shall be required for monitoring potentials of multiple structures. The enclosure for the MJB shall be of IP-55 construction made of 12SWG (2.67) W.T. sheet steel if installed indoor and classified type if installed outdoor. The enclosure shall be structure/wall mounted type having removable hinged front shutter with one handle and flush type locking arrangement. Shutter should be provided with closed cell neoprene sealing gaskets. The terminal board shall be of 8mm thick Phenolic laminated sheet on which all terminals shall be made of stainless steel stud, nut and double spring washers of M-4 size for reference cell/measurement cables. The terminal arrangement shall be such that bottom row is utilised for termination of measurement cables from each structure and upper rows one each is allotted for the reference cell cable termination from each structure, hence total number of rows shall be one more than the total number of structures. All cable entries shall be through Aluminum double compression glands. The external bolt, nuts and clamps to be used for mounting the junction box with back plate/structures shall be MS electro-galvanised or Cadmium plated. Shutter should be provided with closed cell neoprene sealing gaskets.

10.09 The weather proof Junction Boxes 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.

10.10 For classified areas, Junction box enclosure shall be of type "Exd" protection Zone 2/Group IIA/IIB application, Temp. Class: T-6, as per IS 5571,5572,2148 & 8289 and relevant IEC/NEC standards. The cable glands shall be FLP double compression type made of Aluminium. Enclosure need to be certified by CMRI. The shutter of the junction box shall be screwed to the body of junction box by using MS electro galvanised/Cadmium plated nut, bolt and washers. The enclosure of the junction box shall be made of cast aluminium. One earthing terminal shall be provided for earthing the junction box.

10.11 It is essential that all cables should fit tight at cable glands. For this purpose vendor need to make openings for glands at junction box or cast/procure cable glands as per cable samples to be procured for C.P.System.
11.00 CENTRAL MONITORING & CONTROL SYSTEM

11.01 Computerized central monitoring and Control is required for the CP System. For this purpose, the T/R unit & permanent reference cells should be connected to Remote Terminal Unit (RTU) consisting of microprocessor based CPS controller with alphanumeric LCD display, memory, real time clock, keypad, battery backup and communication ports or equivalent PLC-SCADA system.

11.02 Central monitoring & control system for UG Piping: RTU/PLC system to be considered for central monitoring & control system for UG piping shall be capable to process minimum 12 analogue input signals (one each for TR Unit output current & voltage and rest for piping to soil potential measurements), 5 digital input signals, 4 analogue output signals and 4 digital output signals for monitoring performance of each TR Unit which shall be considered for plant piping protection.

11.03 Central monitoring & control system for mounded bullet: RTU/PLC system to be considered for central monitoring & control system for each mounded storage bullet shall be capable to process minimum 18 analogue input signals (one each for TR Unit output current & voltage and rest for bullet to soil potential measurements), 5 digital input signals, 4 analogue output signals and 4 digital output signals for monitoring performance of each TR Unit which shall be considered for mounded bullet protection.

11.04 Central monitoring & control system for tank: RTU/PLC system to be considered for central monitoring & control system for each tank shall be capable to process minimum 7 analogue input signals (one each for TR Unit output current & voltage and rest for tank to soil potential measurements), 5 digital input signals, 4 analogue output signals and 4 digital output signals for monitoring performance of each TR Unit which shall be considered for tank protection.

11.05 Central monitoring & control system for UG Vessel: RTU/PLC system to be considered for central monitoring & control system for each UG Vessel shall be capable to process minimum 6 analogue input signals (one each for TR Unit output current & voltage and rest for UG Vessel to soil potential measurements), 5 digital input signals, 4 analogue output signals and 4 digital output signals for monitoring performance of each TR Unit which shall be considered for UG Vessel protection.

11.06 Central monitoring & control system for multiple number of UG Vessel/Tank/Bullet/ UG piping: RTU/PLC system shall be capable to process suitable number of analogue input signals in line with requirements given above for each unit, 5 digital input signals, 4 analogue output signals and 4 digital output signals for monitoring performance of each TR Unit when it shall be considered for multiple number of UG Vessel /Tank/Bullet/ UG piping protection.

11.07 In addition to this some digital and analog (input / output) signal should also be kept as spare capacity.

11.08 Single or multiple RTU/PLC system may be provided for monitoring and control of all TR unit output and monitoring of potential for Piping/Tank/Bullet/Vessel.

11.09 Thus considering few spares minimum analogue inputs, digital inputs, digital outputs and analogue outputs to be processed by each RTU/PLC system is to be designed by vendor for review / approval by BHEL/OWNER. The system should also have inbuilt mechanisms to reduce / nullify induced AC interference voltages.

11.10 The RTU/PLC Unit shall also be provided with 1 No. digital output for switching operation for TR Unit. This output shall be used to turn the rectifier OFF and ON for depolarized and instant "OFF" readings. The rectifier shall have in-built facility to accept these signals and interrupt its output.
supply. The digital input/output channels shall be optically isolated. The RTU/PLC should include a GPS based time synchronization unit for measurement of true OFF potential readings.

11.11 Further, RTU/PLC shall be provided with 1 analogue output that can be used for controlling the various modes of the TR unit for remote control.

11.12 The RTU/PLC should be capable of generating alarms when the parameter limits are violated and it should communicate the alarm data in real time and should not wait for the monitoring software query.

11.13 All CP System parameters shall be monitored and controlled from central control room using suitable software. The communication link between the RTU/PLC and Central monitoring and Control station should be cost effective GSM based wireless technology RS485 / telephone / fibreoptic / ethernet communication whichever is decided by BHEL/OWNER as the communication network. CP System sub-contractor should design, procure and install the requisite communication system and the cables required for this purpose.

11.14 Central monitoring and Control station computer to be provided by the CP System subcontractor shall consist of standalone computer suitable for CP monitoring application with following minimum specifications:

- Intel Core 2 .Duo processor
- Genuine Windows Vista/XP operating system with License
- 2GB DDR2 NECC Dual Channel SDRAM at 667 MHz
- 320 GB SATA II HDD AT 7200 rpm
- 24in Flat Panel LCD Colour Monitor
- CD Rom
- Intel Integrated 10/ 100 Ethernet Network Card
- 1 Serial, 1 Parallel, 6 USB Port
- MS SQL Server 2000
- A3 Laser jet printer (HP make)
- Inbuilt UPS system which can operate up to 30 minutes on full load in case of power failure
- Other standard accessories

11.15 CP System sub-contractor shall also provide necessary Software for Remote Monitoring & Control as well as for printing of CP reports. The software should be compatible to Windows format and MS SQL Server or Oracle database (10g) with proper License should be used.

11.16 REMOTE MONITORING & CONTROLLING CENTRAL CONTROL SYSTEM:

(a) The software and hardware for the proposed SCADA system shall have a proven track record of minimum three years of successful operation in the field of CP monitoring and shall be procured from BHEL/OWNER approved supplier.

(b) The Remote Monitoring & Control Panel (RMCP) shall have a Data Acquisition and Control Hardware operating in Real Time on PC having minimum specification mentioned in item 11.14. A Front End Processor (FEP) is also required that will be responsible for managing the entire communication traffic between the RMCP and RTU/PLC. The unit shall maintain the data flow even in the event that the RMCP computer is not operative.

(c) The T/R Unit Output DC Voltage, DC Current, Reference Electrode Voltages, Alarms are to be extended to RMCP Panel through RTU/PLC units by any of the cost effective communication network such as GSM based wireless technology / RS485 / telephone / fibreoptic / ethernet communication whichever is decided by BHEL/OWNER as the
communication network, for data downloading and remote monitoring & control from master control room.

(d) Each T/R Unit shall accept set point signals for DC Voltage and DC Current from Remote Monitoring & Controlling Panel and accordingly shall control its output from 0 to 100%.

11.17 REMOTE MONITORING SYSTEM - SOFTWARE:

(a) The Remote Monitoring and Control System shall monitor and control all process parameters of Cathodic protection system.

(b) The Monitoring software shall be user friendly, Windows Vista / XP compatible, and should allow easy data transfer to other windows based applications or custom applications having ODBC compliant database. The Software shall have built-in graphic package to display graphical representation of the process on-screen with embedded buttons for switching ON/ OFF TR units.

(c) Data security should be ensured through three different types of Access Levels namely Expert, Supervisory and Operator. It should have provisions to accommodate future need of addition of new TRs or storage Vessel & piping as may be required from time to time.

(d) The software shall be compatible for interfacing of the available CP System monitoring data on LAN at 10 No. nodes for management information system for access and reporting for the management.

(e) The monitoring software should be capable of generating Email, SMS based notification & visual alarm, as and when signals go outside programmed set points and during RTU/PLC failure and TR Unit input power failure. It should generate customized reports as decided by BHEL/ OWNER. The software shall allow configuration of mobile numbers of the OWNERS employees who are responsible for maintenance and in the event of any malfunctioning of the CP system, the software shall send an SMS to the concerned person to enable him to take the corrective action to ensure that system is restored to normal at the earliest.

11.18 The software should generate reports, which can be viewed as well as printed as listed below:

i) A monthly report showing readings from every system. The reports shall highlight readings outside limits and systems, which did not call.

ii) A single page report yearly report for each remote monitoring. This shall be used to show the monthly readings for each site.

iii) At any time, an exception report shall be available. This report shall show the Remote Monitoring system, which called because of abnormal conditions, and the systems that should have called but did not.

iv) A report shall be generated at 1 second logging interval by normal report generator so special marks for proper interruption cycle operation.

v) Alarm Reports: This particular report shall give all information about the alarms, which occurred in any abnormal conditions.

vi) Report information shall be compatible with standard spread sheet programs.

vii) All above reports of different type should be available in graphical presentation, on screen and printer.

viii) Scaling and calibration of analogue channel can be done by use of SCANET Editor Software.

11.19 DATA BASE SECURITY:

Database shall be in the form of SQL Server. The version of SQL shall be SQL 2000. Following security features shall be provided in the server software:

(i) Roles

- Fixed Server Roles
- Fixed Database Roles
- User-Defined Roles
• Application Roles

(ii) Granting and Denying Permissions to Users and Roles
(iii) Ownership Chains
(iv) Cross-database ownership chaining
(v) Use of Security Identifiers
(vi) Object Level Security Implementation
(vii) Several levels of auditing of both events and states
(viii) Support for SSL implementation
(ix) Remote Administration - Secured Terminal Services

11.20 Over and above the above features, the software supplied by the vendor shall have following essential futures to access the database.
• Group Creation
• User Creation
• User Group Allocation
• Password Aging Period
• Maximum Failure Attempts
• Failure Notifications
• Enable - Disable Account Status
• Template Based security setttings
• e-Signature
• Audit Trail
• Access Level Based on the operation
• Access Security Based on Object / User
• Roles and Reasons
• Audit Trail Query Builder
• Password Masking
• Automatic Application Lock out
12.00 Site Survey

12.01 Resistivity Measurement & Calculations:

(a) Wenner's 4 pin method shall be used to carry out soil resistivity measurement.

(b) 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.

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

(d) Soil resistivity shall be computed by the following relation:

\[ P = 2 \pi AR \]

Where

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

12.02 Soil Resistivity Measurement along ROW/ Piping Corridor

(a) 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.

(b) 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.

(c) 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

(d) 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.

12.03 Soil Resistivity Measurement on Anode Ground Bed

(a) 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.

(b) 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.

12.04 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

12.05 CALIBRATION OF SOIL RESISTIVITY METER

Soil resistivity meter should be calibrated at a reputed laboratory before use. The calibration certificate must be furnished to ENGINEER-IN-CHARGE for approval of the meter before use of the same for soil resistivity test at site.

12.06 REPORT PREPARATION

All soil resistivity readings shall be typed and presented in a tabular form giving coordinates and other location reference of each test locations & depth of each reading. The soil resistivity is to be expressed in ohm-cm. Six copies each of soil resistivity report to be furnished to OWNER/BHEL for record.