ELECTRICAL SYSTEM FOR
CONSTRUCTION WATER PUMP STATION
TFL, TALCHER

TECHNICAL SPECIFICATION – CATHODIC PROTECTION POWER SUPPLY MODULE (PC150-TS-0817)

TECHNICAL SPECIFICATION
CATHODIC PROTECTION POWER SUPPLY MODULE (CPPSM)
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1.0 SCOPE

This specification covers the requirements for the design, manufacture and testing of Cathodic Protection Power Supply Module (CPPSM) working on controlled switch mode principle intended to supply power to cathodic protection system.

2.0 CODES AND STANDARDS

2.1 The system design, performance and materials to be supplied shall conform to the requirements of the latest revision of following standards:

- IS: 1248 (Parts-I, 2, 8 & 9) Direct acting indicating analogue electrical measuring instruments and accessories.
- IS: 3700 (Parts-I to 11) Essential rating and characteristics of semiconductor devices.
- IS: 3715 (Parts-I to 4) Letter symbols for semiconductor devices.
- IS: 4411 Code of designation of semiconductor devices.
- IS: 6619 Safety code for semiconductor rectifier equipment.
- IS: 7204 (Parts-I to 4) Stabilised power supplies DC output.
- IS: 12021 (Parts-I to 4) Control transformers for switchgear and control gear for voltages not exceeding 1000 V AC.
- IS: 13703 (Parts-I to 4) Low voltage fuses for voltages not exceeding 1000 V AC or 1500 V DC.
- IS: 13947 (Parts-4, section-I) Low voltage switchgear and control gear.

2.2 In case of imported equipment, standards of the country of origin shall be applicable if these standards are equivalent or stringent than the applicable Indian standards.

2.3 The equipment shall also conform to the provisions of Indian Electricity rules and other statutory regulations currently in force in the country.

2.4 In case of any contradiction between various referred standards/s specifications/ and statutory regulations the following order of priority shall govern:

- Statutory regulations.
- This specification.
- Codes and standards.

3.0 SITE CONDITION

The CPPSM shall be suitable for installation in non-air-conditioned room with restricted ventilation or in outdoor kiosk in locations having generally corrosive, warm, humid and dusty atmosphere. Service conditions shall be as per actual site conditions. If not specifically mentioned therein, a design ambient temperature of 45°C and an altitude not exceeding 1000 m above mean sea level shall be considered.
4.0 GENERAL REQUIREMENTS

The offered equipment shall be brand new with state of art technology and proven field track record. No prototype equipment shall be offered.

4.1 Vendor shall ensure availability of spare parts and maintenance support services for the offered equipment for at least 15 years from the date of supply.

4.2 Vendor shall give a notice of at least one year to the end user of equipment and owner before phasing out the product/spares to enable the end user for placement of order for spares and services.

5.0 TECHNICAL REQUIREMENTS

5.1 Fabrication and General Details

CPPSM shall be housed in sheet steel enclosure. The front, rear walls and doors shall be made by using minimum 2 mm thick sheet steel and side walls shall be made of minimum 1.6 mm thick sheet steel. Wherever required, suitable stiffeners shall be provided. The Unit shall be freestanding type. Hinged doors "Shall be provided at the front and back as required. The unit shall be natural cooled type. Louvered openings with wire mesh for natural ventilation may be provided. Degree of protection for the panel shall be minimum IP-41. The CPPSM panel shall, preferably, not need rear access for operation, maintenance and shall be suitable for mounting flushed to the wall.

5.1.2 Suitable hooks shall be provided for lifting the panel. These hooks when removed shall not leave any hole in the panel or imperfection in the paint finish.

5.1.3 All instruments shall be panel mounted type and back connected. All fuses shall be provided inside the panel and shall be of link type. 660 V grade PVC insulated BIS approved wires with stranded copper conductor of size minimum 2.5 mm² shall be used for power and auxiliary wiring. Control wiring for electronic circuits shall be through flat ribbon cable or through copper wire of minimum 0.5 mm diameter. All wirings shall be ferruled with PVC ferrules at both ends for ease of identification. Clamp type terminals suitable for termination up to 10 mm² conductor shall be provided for all control cable connection. Suitable power terminals shall be provided for power cables. Minimum 20% spare terminals shall be provided. The terminal blocks shall be mounted minimum 300 mm above the gland plate.

5.1.4 All live parts shall be properly shrouded. This shall ensure complete safety to personnel intending routine maintenance by opening the panel doors.

5.1.5 CPPSM shall be suitable for bottom cable entry unless otherwise specified and shall be supplied complete with crimping type tinned copper lugs and cable glands. Cable glands shall be of rolled aluminium single compression type for indoor installations and double compression type for outdoor installations. The space in the terminal chamber shall be adequate for termination of required number and sizes of cables.

5.1.6 The CPPSM shall be field proven. The design, internal component layout and rating of component shall ensure high MTBF and low MTTR. Prototype equipment shall not be acceptable. Layout of panel components shall enable easy access to the components for maintenance.
5.1.7 All the control equipment like switches, push buttons, potentiometers etc. shall be located at a convenient height of minimum 300 mm and maximum 1800 mm from the bottom of the panel.

5.1.8 The printed circuit boards (PCBs) shall be of copper clad glass epoxy laminate. PCB tracks shall be tinned and solder masked. The PCB shall be coated with suitable lacquer to make it immune to dust, moisture and fungal growth. Where plug in type of PCBs are used gold plated male-female connectors shall be used for the purpose.

5.1.9 If required the panel shall be provided with space heater to prevent moisture condensation. The space heaters shall be located at the bottom of the panel and shall be provided with a manually operated switch and HRC fuse. The space heater shall have porcelain-insulated connectors. Where space heater is not provided, the electronic PCBs/components and other control devices shall be made immune to moisture condensation.

5.1.10 Panel shall be provided with integral base frame channel. The integral base frame of panel shall be suitable for directly bolting with the help of foundation bolts and shall also be suitable for tack welding to purchaser's insert plate/flat/channel embedded in the floor. Amply dimensioned oblong holes shall be provided at the bottom of the panel for its bolting to the embedded insert plate/channel.

5.1.11 An earth bus bar of minimum (25 x 3) mm² copper or equivalent aluminium shall be provided throughout the length of the panel. Provision shall be made for connecting this earth bus at two ends with the plant earth grid by means of (40x5) mm" GI flat. All non-current carrying metallic parts of the panel and mounted equipment shall be connected to the panel earth bus. All doors and movable parts shall be connected to the earth bus by flexible copper cables.

5.1.12 All panel mounted equipments (e.g. lamps, push buttons, switches, meters, PCBs, etc.) shall be provided with suitable nameplates. Nameplates shall be engraved out of 3-ply (black-white-black) lamicoid sheets or anodised aluminium. Back-engraved perspex sheet nameplates may also be acceptable. Engraving shall be done with groove cutters. Hard paper or self-adhesive plastic tape nameplates shall not be acceptable. Nameplates shall be fastened by screws and not by adhesive. Labels shall be provided for every component on the cards, connecting wires as well as for the terminals in the terminal strip inside the panel.

5.1.13 Where specified, the CPPSM shall be housed in an outdoor kiosk. The kiosk shall be made of sheet steel of minimum 3 mm thick and epoxy painted on both internal and external surfaces. Hinged lockable doors shall be provided at the front and back. Acrylic transparent glass window shall be provided on the front door of the kiosk so that the meters, indications and positions of the control switches on the CPPSM can be seen without opening the door of the kiosk. The kiosk shall be suitable for outdoor mounting and shall give proper protection to the CPPSM against rain, other harsh weather conditions. Necessary ventilation arrangement with louvers and wire mesh shall be provided for proper operation of the CPPSM. The cable entry to the kiosk shall be from bottom through cable glands. Suitable canopy shall be provided on the top of the kiosk.

5.1.14 **Painting**

All metal surfaces shall be thoroughly cleaned and degreased to remove mill scale, rust, grease and dirt.
Fabricated structures shall be pickled and then rinsed to remove any trace of acid. The under surface shall be prepared by applying a coat of phosphate paint and a coat of yellow zinc chromate primer. The undersurface shall be made free from all imperfections before undertaking the finishing coat.

After preparation of the under surface, the panel shall be spray painted with two coats of final paint or shall be powder coated. Colour shade of final paint shall be approved by the purchaser before final painting is started. The finished panels shall be dried in stowing ovens in dust free atmosphere. Panel finish shall be free from imperfections like pin holes, orange peels, run off paint, etc.

All unpainted steel parts shall be cadmium plated or suitably treated to prevent corrosion. If these parts are moving elements, then they shall be greased.

6.0 EQUIPMENT DESCRIPTION

The CPPSM shall be complete with following main sections:
- Input controls.
- Power converter and filters.
- Output protections
- System controls
- Current interrupter
- Control, indication and metering

6.1 Input Controls

6.1.1 A moulded case circuit breaker with thermal over load and short circuit release (rated for the input power supply short circuit current) shall be provided at the input for power supply control.

6.2 Power Converter and Filters

6.2.1 The CPPSM shall convert and control the input DC power supply voltage/current into variable DC output voltage/current through switching power semiconductor devices (Thyristor/power transistor/power MOSFET, etc.). The variation in the output voltage/current shall be achieved through control of duty cycle of conduction of the switching power semiconductor devices. The current and voltage ratings of the power semiconductor devices shall be at least two times the maximum device current and min. two times the maximum voltage coming across it respectively. The voltage rating of the power semi-conductor devices shall be co-ordinated with the breakdown voltage of lightning arrester provided at the output so that the power semiconductor devices are protected from any voltage surge coming from the pipeline. Shunt zeners / MOV shall be provided across the power semiconductor devices for protection. The power semiconductor devices shall have humidity/moisture resistant finish and mounted in sufficiently sized heat sink designed to provide adequate cooling under worst conditions of operation. The power semiconductor devices shall have adequate protection against high dv/dt and di/dt.

6.2.2 Where specified, the converter shall electrically isolate the input power to CPPSM from its output so that the grounding of the positive output of the CPPSM through anode ground bed shall not affect the grounding system of the input power supply. Alternatively, a separate DC to DC converter having electrical isolation between input and output power supply shall be provided at the input of the CPPSM.
6.2.3 The power semiconductor devices shall be protected by semiconductor fuses or the system shall have instantaneous short circuit-current limit feature to protect the devices against output short circuits. An adjustable output over current limit feature shall be provided.

6.2.4 Filter shall be provided in the input power supply circuit to minimise the AC injected into the DC input power supply system.

6.2.5 Adequate filtering shall be provided on the DC output of the converter to limit the ripple content in the output to less than 5% at rated output.

6.2.6 The converter system shall be of natural air cooled type.

6.2.7 For CPPSMs with multiple output circuits, each output circuit shall have independent output converter and output filters.

6.3 Output Protections

Two pole moulded case circuit breaker or miniature circuit breaker rated for the DC output current, short circuit current and having thermal over load, short circuit release shall be provided in the output. A lightning arrester rated for minimum 10KA impulse current discharge capacity and rated voltage & max. spark over voltage rating suitable to protect the CPPSM components against lightning and switching surges shall be provided at the output. For CPPSMs with multiple output circuits, each output circuit shall have independent protections.

6.4 System Controls

6.4.1 The CPPSM shall have two distinct modes of operation (independent for each output circuit) as below:

a) Constant Voltage - Constant Current Mode (CVCC)

In this mode the output voltage (Vos) of CPPSM shall be continuously adjustable from 0.5V DC to the rated output voltage. Current limit feature shall be provided in this mode of operation. The current limit (ios) shall be continuously adjustable from zero to rated output current.

For constant voltage mode of operation the output current limit shall be set at maximum and output voltage setting shall be varied. Irrespective of output current demand the chosen value of the output voltage shall be maintained by the control system till the current limit is reached. After that the output current limit shall be maintained and output voltage shall decrease to keep the current constant.

For constant current mode of operation the output voltage shall be set at maximum and output current shall be varied through varying the setting of output current limit. Irrespective of output voltage requirement the control system shall maintain the output current to the set current limit value till the voltage limit is reached. After that the output voltage limit shall be maintained and output current shall decrease to keep the voltage constant.

b) Auto PSP Mode

In this mode of operation the output of the CPPSM shall operate in an external closed loop with pipe-to-soil potential (PSP) in feedback loop. The CPPSM control shall adjust the output voltage such that the PSP as measured by reference cell
always remains equal to the set potential on the unit. The set potential (Vps) shall have high long time stability and minimum temperature drift. The set potential shall be continuously adjustable over the range as required. An adjustable over current limit shall be provided to limit the maximum output current.

The unit shall be designed to operate with the number of reference cells connected to it (to be provided by others). In case of more than one reference cell being specified, CPPSM shall have feature to automatically select the reference cell having less negative potential than the others and use the same for auto control of the unit (e.g. (-) 0.8 V is less negative than (-) 0.9 V). Adequate hysteresis shall be provided in selecting the less negative potential reference cell, to avoid hunting between the reference cells at change over conditions.

In case of open circuit or short circuit of the reference cell or potential being less negative than a minimum set potential (Vrs), for the controlling reference cell, the unit shall sense these conditions as reference cell failure and shall automatically switch over to the other healthy reference cell for control. Should fault occur in all the reference cells, the output voltage or current of the CPPSM shall adjust automatically to a preset value (Vas/las), which shall be adjustable.

In both CVCC and auto PSP modes of operation the electronic over current limit shall be fast enough to protect the active devices of the unit and fast enough to act before tripping of MCCB/MCB or blowing of fuse.

6.4.2 The unit shall continuously monitor the PSP and necessary annunciation shall be provided in case of PSP either exceeding the specified maximum limit (Vpm) or remaining lower than the specified minimum limit (Vpn).

6.4.3 The output voltage regulation for no load to full load variation with input voltage variation from maximum to minimum shall not be more than 2.5 % of rated voltage throughout the range of output voltage and over the specified ambient temperature variation, in CVCC-constant voltage mode of operation. In auto PSP mode the closed loop PSP regulation for no load to full load variation with input voltage variation from maximum to minimum shall be within 20mV throughout the PSP setting range specified.

In CVCC-constant current mode of operation, the current regulation for minimum to maximum output voltage and minimum to maximum variation in input voltage shall not be more than 2.5% throughout the range of output current.

6.4.4 The output of the unit shall be ungrounded and shall allow grounding of positive terminal of the output through the anode ground bed.

6.4.5 For CPPSMs with multiple output circuits, each output circuit shall have independent control system.

6.5 Current Interrupter

6.5.1 If required a current interrupter for CPPSM output current interruption shall be provided.

6.5.2 The current interrupter shall have an output contactor with current rating minimum 125% of the output current rating of the CPPSM and a digital timer to operate it.

6.5.3 The timer shall have ‘ON’ and ‘OFF’ timings. When the timer is turned on the ‘ON’ timing shall start and shall close the output contactor till the end of the ‘ON’ timing. At the end of the ‘ON’ timing the ‘OFF’ timing shall start and keep the contactor open till the end of the
'OFF' timing. At the end of the 'OFF' timing the 'ON' timing shall start again. This process of 'ON' and 'OFF' timing shall continue.

6.5.4 The 'ON' and 'OFF' timings of the timer shall be settable by separate 2 digit thumbwheel switches, each settable from 1 to 99 seconds. The timing error of the timer shall be less than 5 parts per million. In case of microprocessor based system keypad with display may be provided in place of thumbwheel switches.

6.5.5 Whenever the timer is switched on it shall always start with ON ‘timing’. A timer-reset push button shall be provided. On pressing this pushbutton during operation of the timer, the timer shall get reset and upon release of the button, the timer shall restart with 'ON' timing.

6.5.6 The power required for operation of the timer and contactor shall be derived from the main power supply to the CPPSM.

6.5.7 The following controls and indications shall be provided for current interrupter. The controls shall be housed in a lockable cover, so that normally they are not accessible. The indications shall be mounted on the door.

a) Controls
   - Timer power 'ON' / 'OFF'
   - Timer reset
   - Thumb wheel switch for 'ON' timing
   - Thumb wheel switch for 'OFF' timing

   In case of microprocessor based system, keypad with display may be provided in place of thumbwheel switches.

b) Indications (LED)
   - Timer power 'ON'
   - 'ON' timing
   - 'OFF' timing

6.5.8 The output contact of the current interrupter contactor shall be wired in the positive DC output of the CPPSM. A link shall be provided for shorting these terminals whenever the current interrupter is not in use.

6.5.9 If required the current interrupter shall be an independent unit of portable type. The interrupter unit shall have terminals for input power supply and terminals of the contactor in the timer output. The input power supply and the rating of the timer output contactor shall be as required.

6.5.10 Where the current interrupter is not specified with CPPSM or is specified as portable type external to the CPPSM, then the CPPSM shall have provision for connection of input power supply terminals and output contacts of external current interrupter for current interruption test. A link shall be provided for shorting the output terminals provided in CPPSM for current interruption, whenever the current interrupter is not connected.

6.5.11 For CPPSMs with multiple output circuits, each output circuit shall have independent current interrupter.

6.6 Controls, Indication and Metering

6.6.1 Following controls shall be provided on CPPSM front door.

a) ON/OFF control for input through MCCB.
b) ON /OFF control for output through MCCB/MCB.

c) Auto/CVCC mode selector switch.

d) Potentiometers for Vos, Vps and los settings.

e) Selector switch for selecting indication of PSP set and PSP actual for all the reference cells.

6.6.2 Following controls shall be provided inside the module at user accessible common location:

a) Potentiometer for Vrs, Vpm, Vpn and Vas/IAS settings.

b) Controls for current interrupter:
   - Timer power 'ON' / 'OFF'
   - Timer reset
   - Thumb wheel switch for 'ON' timing
   - Thumb wheel switch for 'OFF' timing

6.6.3 CPPSM shall have following indicating lights (lamps or minimum 5 mm dia LEDs):

a) CPPSM ON/OFF

b) Unit in auto/CVCC (2 lamps)

c) Reference cell controlling the closed loop control of the CPPSM (number of lamps same as number of reference cells).

d) Reference cell faulty (number of lamps same as number of reference cells).

e) Pipeline over protected.

f) Pipeline under protected

g) Indications for current interrupter:
   - Timer power 'ON'
   - 'ON' timing
   - 'OFF' timing

It shall be possible to switch-off all the indication lamps by a single switch. In case of LED indication lights this facility may not be provided.

6.6.4 Following meters having min cl. 1.5 accuracy shall be provided on the CPPSM:

a) Digital meter for output voltage

b) Digital meter for output current
c) Digital voltmeter to measure PSP set (Vps) and PSP actual for all the reference cells. The meter shall have range from (-) 4 V to 0 V and shall have cl. 0.5 accuracy.

e) Digital meters for measuring Vrs, Vpm, Vpn and Vas/ias settings.

f) Meters for input voltage and current

It shall be possible to switch-off all the digital meters preferably by a single switch.

6.6.5 If specified, CPPSM shall incorporate provision for remote monitoring of the unit through SCADA system as below:

a) Potential free contacts for the following:
   - All the reference cells failed. (Contact open on alarm condition)
   - Pipeline overprotected. (Contact open on alarm condition)
   - Pipeline under protected. (Contact open on alarm condition)
   - System in auto-mode. (Contact close in auto condition)
   - System in CVCC mode. (Contact close in CVCC mode)

b) 4 to 20 mA electrically isolated signal for the following:
   - PSP (-4V to OV)
   - CPPSM output voltage
   - CPPSM output current

The transducers shall have electrical isolation between input and output. The isolation insulation shall withstand 2 kV, 50 Hz for minimum 1 minute. The accuracy class of the transducer shall be 0.5. The transducers shall be protected against input and output voltage surges. The transducer shall be suitable for driving upto 600 ohms load impedance located upto 500 m away and wired with 0.5 mm- copper conductor cable. The transducers shall be suitable for minimum 125% continuous over load in the input voltage/current parameter.

6.6.6 For units having multiple outputs, each output circuit shall have independent controls, indication and metering.

7.0 TESTS AND ACCEPTANCE

7.1 During fabrication, the equipment shall be subjected to inspection by owner or his authorised representative to assess the progress of the work as well as to ascertain that only quality raw materials are used for the same. He shall be given all assistance to carry out the inspection.

7.2 Final acceptance test shall be carried out at manufacturer's works under his care and expense. Instruments and equipments required for testing shall be arranged by manufacturer. Owner's representative shall be given minimum 2 weeks prior notice for witnessing the tests. Test certificates indicating test results shall be furnished by the manufacturer. Acceptance tests shall include but not be limited to the tests listed below.
7.2.1 Visual Inspection

This shall include-
- Completeness of the equipment in line with specification.
- Checking of all settings.
- All labels provided and satisfactory.
- Dimensional checking.
- Proper mounting of components and neatness of wiring etc.
- Model number.

7.2.2 Insulation tests

The voltage specified in the table below shall be applied for one minute to the circuits indicated:

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<th>Power electronics $U_n$</th>
<th>Auxiliary circuits $U_{n2}$</th>
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<tr>
<td>To earth</td>
<td>700VD.C.</td>
<td>2$xU_n$ + 1000V</td>
<td>2$xU_{n2}$ + 1000V</td>
</tr>
<tr>
<td>To control electronics</td>
<td>-</td>
<td>2$xU_n$ + 1000V</td>
<td>2$xU_{n2}$ + 1000V</td>
</tr>
<tr>
<td>To power electronics</td>
<td>2$xU_{n2}$ + 1000V</td>
<td>-</td>
<td>2$xU_{n2}$ + 1000V</td>
</tr>
<tr>
<td>To auxiliary circuits</td>
<td>2$xU_{n2}$ + 1000V</td>
<td>2$xU_n$ + 1000V</td>
<td>-</td>
</tr>
</tbody>
</table>

($U_n$ and $U_{n2}$ are nominal voltage rating of power electronics and auxiliary circuits respectively).

D.C. test voltages may be applied instead of A.C. The magnitude of D.C. test voltages to be applied shall be 2 times the above-mentioned A.C. (r.m.s) Values.

Insulation resistance test shall be conducted before and after heat run test.

7.2.3 Heat run test

All CPPSMs shall be subjected to a heat run test performed at rated voltage for period not less than 16 hours prior to execution of functional tests.

At least one CPPSM of each rating shall be loaded to its rated output throughout 16 hour test period. All other CPPSMs shall be energized under partial load or zero load current condition throughout the test period.

7.2.4 Functional tests
Functional tests as below shall be performed on each CPPSM. If during execution of functional tests, any electronic component of the unit is required to be replaced e.g. due to malfunction or failure of the unit to fulfill the performance requirements of the specification, then the load test shall be repeated at rated current following which functional tests shall be carried out.

7.2.4.1 CVCC mode operation testing

a) Constant voltage operation

During the test, current limit shall be set to rated output current. Performance testing shall be carried out for various output voltage settings and load varying from zero to maximum. The verification of operation of the control functions, measurement of output voltage, current, input voltage, current, ripple in the output, input, evaluation of output voltage regulation and efficiency of the unit shall be carried out during the testing.

b) Constant current operation

During the test, voltage limit shall be set to rated output voltage. Performance testing shall be carried out for various output current limit settings and load resistance varied to achieve output voltage from minimum to maximum. The verification of operation of the control functions, measurement of output voltage, current, input voltage, current, ripple in the output, input, evaluation of output current regulation of the unit shall be carried out during the testing.

7.2.4.2 Auto PSP mode operation

Suitable set-up shall be arranged for output loading and reference cell feedback. The closed loop performance and regulation shall be checked with the PSP set voltage varied from 0.85V to 1.2V.

Disconnecting the reference cell feedback connection in the above set up shall simulate the reference cell failed condition. The output voltage/current of the unit shall go to the value set on the potentiometer Vas/las provided inside the CPPSM. The settings on Vas/las shall be varied and the output voltage/current shall be observed.

7.2.4.3 Operation of sensors for pipeline over protection, under protection, reference cell failure and reference cell selection logic in auto PSP mode shall be verified by connecting variable external voltage sources to reference cell inputs of the CPPSM. The number of external voltage sources shall be same as number of reference cell inputs specified for the CPPSM.

7.2.4.4 The unit shall be checked for operation of the current limit by over loading the unit in both CVCC and auto PSP modes of operation. For Units where semiconductor fuses are not provided for protection of the power semiconductor device, the protection of same shall be tested as below:

A switch rated for making and carrying CPPSM output short circuit current shall be connected to the output terminals of the unit. The output voltage and the output current limit settings of the unit shall be set to the maximum rated values. The switch connected in the output shall be shorted quickly.

The unit shall go to current limit mode and shall not damage any active component of the unit.
7.2.4.5 The current interrupter shall be tested for time interval settings and specified operation.

8.0 PACKING AND DESPATCH

The equipment shall be properly packed for selected mode of transportation i.e. by ship/rail or trailer. The panels shall be wrapped in polythene sheets before being placed in crates to prevent damage to finish. Crates shall have skid bottom for handling. Special notations such as 'Fragile', 'This side up', 'Centre of gravity', 'Weight' etc., shall be clearly marked on the package together with Tag nos., P.O. Nos. etc.

The equipment may be stored outdoors for long periods before erection. The packing shall be completely suitable for outdoor storage in areas with heavy rains/high ambient temperature.

9.0 DEVIATIONS

9.1 Deviations, if any, from this standard shall be clearly indicated in the offer with reasoning.
TECHNICAL SPECIFICATION

CATHODIC PROTECTION TRANSFORMER RECTIFIER UNIT
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1.0 SCOPE

This specification covers the requirements for the design, manufacture and testing of Cathodic Protection Transformer Rectifier units (CPTR units) working on controlled rectification principle intended to supply power to cathodic protection system for underground pipelines/structures.

2.0 CODES AND STANDARDS

2.1 The system design, performance and materials to be supplied shall conform to the requirements of the latest revision of following standards:

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- IS: 13947 (Parts-4, section-I) Low voltage switchgear and control gear.

2.2 In case of imported equipment, standards of the country of origin shall be applicable if these standards are equivalent or stringent than the applicable Indian standards.

2.3 The equipment shall also conform to the provisions of Indian Electricity rules and other statutory regulations currently in force in the country.

2.4 In case of any contradiction between various referred standards/ specifications and statutory regulations the following order of priority shall govern:

- Statutory regulations.
- This specification.
- Codes and standards

3.0 SITE CONDITIONS

The CPTR unit shall be suitable for installation in non air-conditioned room with restricted ventilation or in outdoor kiosk, in locations having generally corrosive, warm, humid and dusty atmosphere. Service conditions shall be as actual site conditions. If not specifically mentioned therein, a design ambient temperature of 45°C and an altitude not exceeding 1000 m above mean sea level shall be considered.

4.0 GENERAL REQUIREMENTS
4.1 The offered equipment shall be brand new with state of art technology and proven field track record. No prototype equipment shall be offered.

4.2 Vendor shall ensure availability of spare parts and maintenance support services for the offered equipment for at least 15 years from the date of supply.

4.3 Vendor shall give a notice of at least one year to the end user of equipment and PDIL before phasing out the product/spares to enable the end user for placement of order for spares and services.

5.0 TECHNICAL REQUIREMENTS

5.1 Fabrication and General Details

5.1.1 CPTR unit shall be housed in sheet steel enclosure. The front, rear walls and doors shall be made by using minimum 2 mm thick sheet steel and side walls shall be made of minimum 1.6 mm thick sheet steel. Wherever required, suitable stiffeners shall be provided. The Unit shall be freestanding type. Hinged doors shall be provided at the front and back as required. The unit shall be natural cooled type. Louvered openings with wire mesh for natural ventilation may be provided. Degree of protection for the panel shall be minimum IP-41. The CPTR unit panel shall, preferably, not need rear access for operation, maintenance and shall be suitable for mounting flushed to the wall.

5.1.2 Suitable hooks shall be provided for lifting the panel. These hooks when removed shall not leave any hole in the panel or imperfection in the paint finish.

5.1.3 All instruments shall be panel mounted type and back connected. All fuses shall be provided inside the panel and shall be of link type. 660 V grade PVC insulated BIS approved wires with stranded copper conductor of size minimum 2.5 mm² shall be used for power and auxiliary wiring. Control wiring for electronic circuits shall be through flat ribbon cable or through copper wire of minimum 0.5 mm diameter. All wirings shall be ferruled with PVC ferrules at both ends for ease of identification. Clamp type terminals suitable for termination up to 10 mm conductor shall be provided for all control cable connection. Suitable power terminals shall be provided for power cables. Minimum 20% spare terminals shall be provided. The terminal blocks shall be mounted minimum 300 mm above the gland plate.

5.1.4 All live parts shall be properly shrouded. This shall ensure complete safety to personnel intending routine maintenance by opening the panel doors.

5.1.5 CPTR unit shall be suitable for bottom cable entry unless otherwise specified and shall be supplied complete with crimping type cable termination lugs and cable glands. Cable glands shall be of rolled aluminium, single compression type for indoor installations and double compression type for outdoor installations. The space in the terminal chamber shall be adequate for termination of required number and sizes of cables.

5.1.6 The input power factor of the unit at rated load shall be 0.8 lag or better.

5.1.7 The CPTR unit shall be field proven. The design, internal component layout and rating of component shall ensure high MTBF and low MTTR. Prototype equipment shall not be acceptable.

5.1.8 All the control equipment like switches, pushbuttons, potentiometers etc. shall be located at a convenient height of minimum 300 mm and maximum 1800 mm from the bottom of the panel.
5.1.9 The printed circuit boards (PCBs) shall be of copper clad glass epoxy laminate. PCB tracks shall be tinned and solder masked. The PCB shall be coated with suitable lacquer to make it immune to dust, moisture and fungal growth. Where plug in type of PCBs are used gold plated male-female connectors shall be used for the purpose.

5.1.10 If required the panel shall be provided with space heater to prevent moisture condensation. The space heaters shall be located at the bottom of the panel. and shall be provided with a manually operated switch, HRC fuse and link for phase and neutral respectively. The space heater shall have porcelain connectors. Where space heater is not provided the electronic PCBs/components and other control devices shall be made immune to moisture condensation.

5.1.11 Panel shall be provided with integral base frame channel. The integral base frame of panel shall be suitable for directly bolting with the help of foundation bolts and shall also be suitable for tack welding to purchaser's insert plate/flat/channel embedded in the floor. Amply dimensioned oblong holes shall be provided at the bottom of the panel for its bolting to the embedded insert plate/channel.

5.1.12 An earth bus bar of minimum (25 x 3) m² copper or equivalent aluminium shall be provided throughout the length of the panel. Provision shall be made for connecting this earth bus at two ends with the plant earth grid by means of (40x5) mm- GI flat. All non-current carrying metallic parts of the panel and mounted equipment shall be connected to the panel earth bus. All doors and movable parts shall be connected to the earth bus by flexible copper cables.

5.1.13 All panel mounted equipments (e.g. lamps, pushbuttons, switches, meters, PCBs, etc.) shall be provided with suitable nameplates. Nameplates shall be engraved out of 3-ply (black-whiteblack) lamicoid sheets or anodised aluminium. Back-engraved Perspex sheet nameplates may also be acceptable. Engraving shall be done with groove cutters. Hard paper or self-adhesive plastic tape nameplates shall not be acceptable. Nameplates shall be fastened by screws and not by adhesive. Labels shall be provided for every component on the cards, connecting wires as well as for the terminals in the terminal strip inside the panel.

5.1.14 Where specified, the CPTR unit shall be housed in an outdoor kiosk. The kiosk shall be made of sheet steel of minimum 3 mm thick and epoxy painted on both internal and external surfaces. Hinged lockable doors shall be provided at the front and back. The kiosk shall be suitable for outdoor mounting and shall give proper protection to the CPTR unit against rain, other harsh weather conditions. Necessary ventilation arrangement with louvers and wire mesh shall be provided for proper operation of the CPTR unit. The cable entry to the kiosk shall be from bottom through cable glands. Suitable canopy shall be provided on the top of the Kiosk.

5.1.15 **Painting**

All metal surfaces shall be thoroughly cleaned and degreased to remove mill scale, rust, grease and dirt.

Fabricated structures shall be pickled and then rinsed to remove any trace of acid. The under surface shall be prepared by applying a coat of phosphate paint and a coat of yellow zinc chromate primer. The under surface shall be made free from all imperfections before undertaking the finishing coat.

After preparation of the under surface, the panel shall be spray painted with two coats of final paint or shall be powder coated. Colour shade of final paint shall be approved by the purchaser before final painting is started. The finished panels shall be dried in stowing
ovens in dust free atmosphere. Panel finish shall be free from imperfections like pin holes, orange peels, run off paint, etc. All unpainted steel parts shall be suitably treated to prevent corrosion. If these parts are moving elements, then they shall be greased.

6.0 EQUIPMENT DESCRIPTION

The CPTR unit shall be complete with following main sections:
- Transformer and input controls.
- Rectifier and filter
- Output protections
- System controls
- Control, indication and metering

6.1 Transformer and Input Controls

6.1.1 The transformer shall be natural cooled dry type with separate primary and secondary windings.

An intermediate earth screen shall be provided between primary and secondary windings. CPTR Units having multiple output circuits shall have separate secondary windings for each output circuit. Transformer shall be vacuum impregnated with epoxy varnish and baked. The safety factor for transformer rating shall be minimum 125%.

6.1.2 Single-phase transformers may be provided up to 50V, 50A DC output rating of the CPTR units. Beyond this rating, 3 phase transformers shall be provided. A moulded case circuit breaker with thermal overload and short circuit release shall be provided at the input of the transformer. Miniature circuit breaker with thermal overload and short circuit release in place of moulded case circuit breaker may be provided, where the miniature circuit breaker rated for the incoming AC supply short circuit current.

6.2 Rectifier and Filters

6.2.1 The rectifier shall be made of thyristors and diodes as basic components. The CPTR unit shall be suitable for 415 V AC, 3-ph power supply. Rectifier shall be 3 phase full wave type and controlled type. For CPTR units rated 50V, 50A DC or less, the unit may be suitable for 240V AC, 1 ph power supply and the rectifier shall be full wave type and controlled type. Alternatively, for single phase AC CPTR units, diode rectifier of full wave type in the secondary of the transformer and triac or back to back connected thyristors in the transformer primary AC supply circuit may be provided. The current and voltage ratings of thyristors, diodes shall be at least two times the actual maximum device current and minimum two times the actual maximum voltage coming across the device respectively. The thyristors/ triac/ rectifier elements shall be protected against voltage surges coming from the incoming power supply and from output side from the pipeline. Required shunt zeners / MOV shall be provided across the rectifier elements for protection.

The rectifier elements shall have humidity/moisture resistant finish and mounted in sufficiently sized heat sink designed to provide adequate cooling under worst conditions of operation. The rectifier elements shall have adequate protection against high dv/dt and di/dt. 6.2.2 The thyristors/triacs shall be protected by semiconductor fuses. For units rated 50V, 50A DC or less, if the thyristors or triacs are adequately over rated and system has enough inductance so that in case of sudden output short circuit the over current limit feature comes into action before short circuit current rises beyond the rating of the thyristors/triacs, then the semiconductor fuses may not be provided. This feature shall be demonstrated during testing of the unit at works.

6.2.3 Adequate filtering shall be provided on the DC output of the rectifier to limit the ripple content in the output to less than 5% at rated output.
6.2.4 The rectifier system shall be of natural air cooled type.

6.2.5 For CPTR units with multiple output circuits, each output circuit shall have independent rectifier and filter.

6.3 Output Protections

Two pole moulded case circuit breaker or miniature circuit breaker (if available) rated for the DC output current, short circuit current and having thermal overload, short circuit release shall be provided in the output. A lightning arrester rated for minimum 10KA impulse current discharge capacity and rated voltage & maximum spark over voltage rating suitable to protect the CPTR unit components against lightning and switching surges shall be provided at the output. For CPTR units with multiple output circuits, each output circuit shall be provided with circuit breaker and lightning arrester.

6.4 System Controls

6.4.1 The CPTR unit shall have two distinct modes of operation (independent for each output circuit) as below:

a) Constant Voltage and Constant Current Mode (CVCC)

In this mode the output voltage of CPTR unit shall be continuously adjustable from 0.5V DC to the rated output voltage. The set output voltage (Vos) shall remain constant irrespective of output current. Current limit feature shall be provided. The current limit (los) shall be continuously adjustable from zero to rated output current.

For constant voltage mode of operation the output current limit shall be set at maximum and output voltage setting shall be varied. Irrespective of output current demand the chosen value of the output voltage shall be maintained by the control system till the current limit is reached. After that the output current limit shall be maintained and output voltage shall decrease to keep the current constant.

For constant current mode of operation the output voltage shall be set at maximum and output current shall be varied through varying the setting of output current limit. Irrespective of output voltage requirement the control system shall maintain the output current to the set current limit value till the voltage limit is reached. After that the output voltage limit shall be maintained and output current shall decrease to keep the voltage constant.

b) Auto PSP Mode

In this mode of operation the output of the CPTR unit shall operate in an external closed loop with pipe to soil potential (PSP), measured by reference cell, in feedback loop. The CPTR unit control shall adjust the output voltage such that the PSP as measured by reference cell always remains equal to the set potential on the unit. The set potential (Vps) shall have high long time stability and minimum temperature drift. The set potential shall be continuously adjustable over the range required.

The unit shall be designed to operate with number of reference cells connected to it (to be provided by others). In case of more than one reference cell being specified, CPTR unit shall have feature to automatically select the reference cell having less negative potential than the others and use the same for auto control of the unit (e.g. (-) 0.8 V is less negative than (-) 0.9 V). Adequate hysteresis shall be provided in selecting the less negative potential reference cell, to avoid hunting between the reference cells at change over conditions.
In case of open circuit or short circuit of reference cell or potential being less negative than a minimum set potential (Vrs), the unit shall sense these conditions as reference cell failure and shall automatically switch over to the other healthy reference cell for control. Should fault occur in all the reference cells, the output voltage or current of the CPTR unit shall adjust automatically to a preset value (Vas/Ias), which shall be adjustable.

In both CVCC and auto PSP modes of operation a fast acting electronic over current limit protection shall be provided. This protection shall be fast enough to protect the active devices of the unit and fast enough to act before tripping of MCCB/MCB or blowing of fuse.

6.4.2 The unit shall continuously monitor the PSP and necessary annunciation shall be provided in case of PSP either exceeding the specified maximum limit (Vpm) or remaining lower than the specified minimum limit (Vpn).

6.4.3 The output voltage regulation for no load to full load variation with input voltage variation from maximum to minimum shall not be more than 2.5 % of rated voltage throughout the range of output voltage and over the specified ambient temperature variation, in CVCC-constant voltage mode of operation. In auto PSP mode the closed loop PSP regulation for no load to full load variation with input voltage variation from maximum to minimum and PSP feedback varying over the specified range shall be within Zf mV.

In CVCC-constant current mode of operation, the current regulation for minimum to maximum output voltage and minimum to maximum variation in input voltage shall not be more than 2.5% throughout the range of output current.

6.4.4 The DC output of the CPTR unit shall be floating (ungrounded) in the Unit. However the CPTR Unit shall allow grounding of positive output terminal through the anode ground bed.

6.4.5 For CPTR units with multiple output circuits, each output circuit shall have independent control system.

6.5 Current Interrupter

6.5.1 If required, a current interrupter for CPTR Unit output current interruption shall be provided.

6.5.2 The current interrupter shall have an output contactor with current rating minimum 125% of the output current rating of the CPTR unit and a digital timer to operate it.

6.5.3 The timer shall have 'ON' and 'OFF' timings. When the timer is turned on the 'ON' timing shall start and shall close the output contactor till the end of the 'ON' timing. At the end of the 'ON' timing the 'OFF' timing shall start and keep the contactor open till the end of the 'OFF' timing. At the end of the 'OFF' timing the 'ON' timing shall start again and close the output contactor. This process of 'ON' and 'OFF' timing shall continue.

6.5.4 The 'ON' and 'OFF' timings of the timer shall be settable by separate 2 digit thumbwheel switches, each settable from 1 to 99 seconds. The timing error of the timer shall be less than 5 parts per million. In case of microprocessor based system keypad with display may be provided in place of thumbwheel switches.

6.5.5 Whenever the timer is switched on it shall always start with ON 'timing'. A timer-reset push button shall be provided. On pressing this pushbutton during operation of the timer, the timer shall get reset and upon release of the button the timer shall restart with 'ON' timing.
6.5.6 The power required for operation of the timer and contactor shall be derived from the main power supply to the CPTR unit.

6.5.7 The following controls and indications shall be provided for current interrupter. The controls shall be housed in a lockable cover, so that normally they are not accessible. The indications shall be mounted on the door.

a) Controls
   - Timer power 'ON' / 'OFF'
   - Timer reset
   - Thumb wheel switch for 'ON' timing
   - Thumb wheel switch for 'OFF' timing

   In case of microprocessor based system keypad with display may be provided in place of thumbwheel switches.

b) Indications (LED)
   - Timer power 'ON'
   - 'ON' timing
   - 'OFF' timing

6.5.8 The output contact of the current interrupter contactor shall be wired in the positive DC output of the CPTR unit. A link shall be provided for shorting these terminals whenever the current interrupter is not in use.

6.5.9 If required the current interrupter shall be an independent unit of portable type. The interrupter unit shall have terminals for input power supply and terminals of the output contactor. The input power supply and the rating of the output contactor shall be as required. Terminals shall be provided in the CPTR unit for taking power supply to the current interrupter.

6.5.10 Where the current interrupter is not specified with CPTR unit or is specified as portable type external to the CPTR unit, then the CPTR unit shall have provision/terminals for connection of input power supply and output contacts of external current interrupter, for current interruption test. A link shall be provided for shorting the output terminals provided in CPTR unit whenever the current interrupter is not connected.

6.5.11 For CPTR units with multiple output circuits, each output circuit shall have independent current interrupter.

6.6 Controls, Indication and Metering

6.6.1 Following controls shall be provided on CPTR unit front door.

a) ON/OFF control for input through MCCB/MCB.

b) ON/OFF control for output through MCCB/MCB.

c) Auto/CVCC mode selector switch.

d) Potentiometers for Vos, Vps and los settings.

e) Selector switch for selecting indication of PSP set and PSP actual for all the reference cells.
6.6.2 Following controls shall be provided inside the module at user accessible common location:

a) Potentiometer for Vrs, Vpm, Vpn and Vas/las settings.

b) Controls for current interrupter:
   - Timer power 'ON' / 'OFF'
   - Timer reset
   - Thumb wheel switch for 'ON' timing
   - Thumb wheel switch for 'OFF' timing

6.6.3 TR unit shall have following indicating lights (lamps or minimum 5 mm dia LEDs):

a) CPTR unit ON/OFF

b) Unit in AUTO/CVCC (2 lamps)

c) Reference cell controlling the closed loop control of the CPTR unit (number of lamps same as number of reference cells).

d) Reference cell faulty (number of lamps same as number of reference cells).

e) Pipeline over protected.

f) Pipeline under protected

g) Indications for current interrupter:
   - Timer power 'ON'
   - 'ON' timing
   - 'OFF' timing

It shall be possible to switch-off all the indication lamps by a single switch. In case of LED indication lights this facility may not be provided.

6.6.4 Following meters having min cl.1.5 accuracy shall be provided on the CPTR unit:

a) Digital meter for output voltage

b) Digital meter for output current

c) Digital voltmeter to measure PSP set (Vps) and PSP actual for all the reference cells. The meter shall have range from -4 V to 0 V and shall have cl.0.5 accuracy.

d) Digital meters for measuring Vrs, Vpm, Vpn and Vas/las settings.

  e) Meters for input voltage and current

It shall be possible to switch-off all the digital meters preferably by a single switch.

6.6.5 If required, CPTR unit shall incorporate provision for remote monitoring of the unit through SCADA system as below:
a) Potential free contacts for the following:
- All the reference cells failed. (Contact open on alarm condition)
- Pipeline overprotected. (Contact open on alarm condition)
- Pipeline under protected. (Contact open on alarm condition)
- System in auto-mode. (Contact close in auto condition)
- System in CVCC mode. (Contact close in CVCC mode)

b) 4 to 20 mA electrically isolated signal for the following:
- PSP (-4V to OV)
- CPTR unit output voltage
- CPTR unit output current

The transducers shall have electrical isolation between input and output. The isolation insulation shall withstand 2kV, 50Hz for minimum 1 minute. The accuracy class of the transducer shall be 0.5. The transducers shall be protected against input and output voltage surges. The transducer shall be suitable for driving up to 600 ohms load impedance located up to 500 m away and wired with 0.5 mm² copper conductor cable.

6.6.6 For units having multiple outputs, each output circuit shall have independent controls, indication and metering.

7.0 TESTS AND ACCEPTANCE

7.1 During manufacture, the equipment shall be subjected to inspection by owner or his authorised representative to assess the progress of the work as well as to ascertain that only quality raw materials are used for the same. He shall be given all assistance to carry out the inspection.

7.2 Final acceptance test shall be carried out at manufacturer's works under his care and expense. Instruments and equipments required for testing shall be arranged by manufacturer. Owner's representative shall be given minimum 2 weeks prior notice for witnessing the tests. Test certificates indicating test results shall be furnished by the manufacturer. Acceptance tests shall include but not be limited to the tests listed below.

7.2.1 Visual Inspection

This shall include-
- Completeness of the equipment in line with specification.
- Checking of all settings.
- All labels provided.
- Dimensional checking.
- Proper mounting of components and neatness of wiring etc.
- Model number.
7.2.2 Insulation tests

The voltage specified in the table below shall be applied for one minute to the circuits indicated:

<table>
<thead>
<tr>
<th>Withstand voltage</th>
<th>Control electronics &lt;60V</th>
<th>Power electronics Un₁</th>
<th>Auxiliary circuits Un₂</th>
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<tr>
<td>To earth</td>
<td>700VD.C.</td>
<td>2xUn₁ + 1000V</td>
<td>2xUn₂ + 1000V</td>
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<tr>
<td>To control</td>
<td>-</td>
<td>2xUn₁ + 1000V</td>
<td>2xUn₂ + 1000V</td>
</tr>
<tr>
<td>electronics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To power electronics</td>
<td>2xUn₂ + 1000V</td>
<td>-</td>
<td>2xUn₂ + 1000V</td>
</tr>
<tr>
<td>circuits</td>
<td>2xUn₂ + 1000V</td>
<td>2xUn₁ + 1000V</td>
<td>-</td>
</tr>
</tbody>
</table>

(Un₁, and Un₂ are nominal voltage rating of power electronics and auxiliary circuits respectively).

D.C. test voltages may be applied instead of A.C. The magnitude of D.C. test voltages to be applied shall be 2 times the above-mentioned A.C. (r.m.s) Values.

Insulation resistance test shall be conducted before and after heat run test.

7.2.3 Heat run test

All CPTR units shall be subjected to a heat run test performed at rated voltage for period not less than 16 hours prior to execution of functional tests.

At least one CPTR unit of each rating shall be loaded to its rated output throughout 16 hour test period. All other CPTR units shall be energized under partial load or zero load current condition throughout the test period.

7.2.4 Functional tests

Functional tests as below shall be performed on each CPTR unit. If during execution of functional tests, any electronic component of the unit is required to be replaced e.g. due to malfunction or failure of the unit to fulfil the performance requirements of the specification, then the load test shall be repeated at rated current following which functional tests shall be carried out.

7.2.4.1 CVCC mode operation testing

a. Constant voltage operation

During the test, current limit shall be set to rated output current. Performance testing shall be carried out for various output voltage settings and load varying from zero to maximum. The verification of operation of the control functions, measurement of output voltage, current, input AC voltage, current, power factor, ripple in the output, evaluation of output voltage regulation and efficiency of the unit shall be carried out during the testing.

b. Constant current operation

During the test, voltage limit shall be set to rated output voltage. Performance testing shall be carried out for various output current limit settings and load resistance varied to
achieve output voltage from minimum to maximum. The verification of operation of the control functions, measurement of output voltage, current, input AC voltage, current, power factor, ripple in the output, evaluation of output current regulation of the unit shall be carried out during the testing.

7.2.4.2 Auto PSP mode operation

Suitable set up shall be arranged for output loading and reference cell feedback. The closed loop performance and regulation shall be checked with the PSP set voltage varied from 0.85V to 1.2V.

Disconnecting the reference cell feedback connection in the above set up shall simulate the reference cell failed condition. The output voltage/current of the unit shall go to the value set on the potentiometer Vas/las provided inside the CPTR UNIT. The settings on Vas/las shall be varied and the output voltage/current shall be observed.

7.2.4.3 Operation of sensors for pipeline over protection, under protection, reference cell failure and reference cell selection logic in auto PSP mode shall be verified by connecting variable external voltage sources to reference cell inputs of the CPTR unit. The number of external voltage sources shall be same as number of reference cell inputs specified for the CPTR unit.

7.2.4.4 The unit shall be checked for operation of the current limit by over loading the unit in both CVCC and auto PSP modes of operation. For Units where semiconductor fuses are not provided for protection of the thyristors/triacs, the protection of same shall be tested as below:

A switch rated for making and carrying CPTR unit output short circuit current shall be connected to the output terminals of the unit. The output voltage and the output current limit settings of the unit shall be set to the maximum rated values. The switch connected in the output shall be shorted quickly.

The unit shall go to current limit mode and shall not damage any active component of the unit.

7.2.4.5 The current interrupter shall be tested for time interval settings and specified operation.

8.0 PACKING AND DESPATCH

The equipment shall be properly packed for selected mode of transportation i.e. by ship/rail or trailer. The panels shall be wrapped in polythene sheets before being placed in crates to prevent damage to finish. Crates shall have skid bottom for handling. Special notations such as 'Fragile', 'This side up', 'Centre of gravity', 'Weight' etc., shall be clearly marked on the package together with Tag nos., P.O. Nos. etc. The equipment may be stored outdoors for long periods before erection. The packing shall be completely suitable for outdoor storage in areas with heavy rains/high ambient temperature.

9.0 DEVIATIONS

9.1 Deviations, if any, from this standard shall be clearly indicated in the offer with reasoning.
TECHNICAL SPECIFICATION

IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM

FOR PIPELINES
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1.0 SCOPE

1.1 This specification defines the requirements of system design, engineering, installation, testing and commissioning of an Impressed Current Cathodic Protection System for underground pipelines / structures including supplementing of corrosion survey, close interval potential logging survey, investigations for interaction/interference problems and mitigation of the same.

1.2 This specification provides the basic parameters to develop a suitable impressed current cathodic protection system for the pipelines/structures requiring protection. LSTK contractor shall include, site survey to collect required information, design, supply, installation, commissioning of impressed current cathodic protection system. All data required in this context shall be taken into consideration to develop an acceptable design and for proper engineering of the system.

1.3 In addition to this specification, other requirement, if any, for complete cathodic protection shall be considered by LSTK contractor.

1.4 Compliance with these specifications, and/or approval of any documents submitted by contractor shall in no case relieve the contractor of his contractual obligations.

2.0 CODES AND STANDARDS

2.1 The system design, performance and materials to be supplied shall conform to the requirements of the latest revision of following standards as a minimum:

i) NACE Standard RP-0169 : Standard Recommended Practice Control of External Corrosion on Underground or Submerged Metallic Piping Systems

ii) NACE Publication l0A190 : Measurement technique related to criteria for CP of Underground or Submerged Steel Piping System (as defined in NACE Standard RPO169-83)

iii) NACE Standard RP-0177 : Standard Recommended Practice Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems

iv) NACE Standard RP-0286 : Standard Recommended Practice The Electrical isolation of Cathodically Protected Pipelines.

v) NACE Publication No. 54276 : Cathodic Protection Monitoring for Buried Pipelines.

vii) DNV RP-B403 : Recommended Practice Monitoring of Cathodic Protection Systems

viii) DNV RP-B401 : Recommended Practice Cathodic Protection Design

ix) IS 8062 : Recommended Practice ICCP for Underground Piping

x) BS 7361 Part I : Code of Practice for Cathodic Protection for land and marine application.

xi) VDE 0150 : Protection against Corrosion due to Stray Current from DC Installations.

xii) IS: 1554 Part I : PVC insulated (heavy duty) cables.

2.2 In case of imported equipments standards of the country of origin shall be applicable if these standards are equivalent or stringent than the applicable Indian standards.

2.3 The equipment shall also confirm to the provisions of Indian Electricity rules and other statutory regulations currently in force in the country.

2.4. In case of any contradiction between various referred standards/specifications and statutory regulations the following order of priority shall govern:
- Statutory regulations
- This specification
- Codes and standards

3.0 SYSTEM IMPLEMENTATION

All work to be performed and supplies to be effected as a part of contract shall require specific review by Owner or his authorised representative. Major activities requiring review shall include but not be limited to the following:

i) Corrosion survey data interpretation report and plot plans for land acquisition.
ii) Conceptual system design.
iii) Basic engineering package.
iv) Detailed engineering package.
v) Field testing and commissioning procedures.
vi) Procedures for interference testing and mitigation
vii) Close interval potential logging survey procedure
viii) As built documents.

4.0 CORROSION SURVEY
4.1 **General**

4.1.1 The details of corrosion survey including soil resistivity data along ROW and other data required for C.P. design if available with the owner shall be included. However, verification of its veracity and adequacy shall be the entire responsibility of the contractor. In addition, contractor shall have to generate/collect additional data as per clause 4.4 below required for completeness of the job.

Contractor shall carry out soil resistivity survey at anode ground bed locations for design of ground bed. Contractor shall also carry out corrosion survey along the ROW of the pipeline.

4.1.2 To carry out soil resistivity measurement Wenner's 4-pin method or an equivalent method approved by Owner shall be used. Survey instruments shall have maximum AC and DC ground current rejection feature.

Care shall be taken to ensure that the resistivity observations are not influenced by the presence of foreign pipelines/structures, and earth currents in the vicinity of EHV/HV lines and installations using earth return in their power system etc.

4.2 **Soil Resistivity Survey at Impressed Current Anode Ground Bed Plot**

4.2.1 Each selected anode bed plot shall be sub-divided into sub-plots. Sizes of sub-plots shall depend upon the expected depth for soil resistivity investigations. Each of these sub-plots shall be investigated for resistivity data individually. Sufficient observations shall be taken at each of these sub-plots as required and desired by Owner/Owner's representative to obtain sufficient information about sub-soil stratification and, wherever possible, to establish the depth of water table. The number of subplots at each ground bed plot shall be decided at site in consultation with Owner/Owner's representative.

4.2.2 Number, location, demarcation and size of sub-plots and number of sets of resistivity observations required for each sub-plot shall be individually decided for each ground bed plot location.

4.2.3 One or more ground bed plots may be required to be selected and surveyed at each CP station to form a suitable ground bed.

4.3 **Topographic Surveys**

Cathodic protection stations consisting of anode ground bed, CP station, etc. As applicable, along with all associated cabling up to pipeline and any other related equipment and accessories for CP station shall be demarcated on the ground. Ground plots so demarcated shall be surveyed for all other topographical and cadastral features and topo-sheets shall be developed by the CONTRACTOR, which shall be suitable for use in land acquisition etc.

4.4 **Additional Data to be Collected**

The following data shall be collected to generate design data for evaluation of interaction/interference possibilities due to presence of other services in ROW or in its vicinity. OWNER shall provide assistance for liaison work to the extent possible.

i) Route and types of foreign service/pipeline in and around or crossing the right of way (including those existing and those which are likely to come up during contract execution).
ii) Diameter, wall thickness, pressure, soil cover, and coating scheme used, type of
cathodic protection system provided, if any, year of laying/commissioning in case of
foreign pipelines.

iii) Details of the existing cathodic protection systems protecting the services i.e. type
of protection, location, type, rating of anode beds, test station locations and their
connection schemes. Present output current and voltage readings of the CP power
supply units.

iv) Remedial measures existing on foreign pipelines/services to prevent interaction.

v) Graphical representation of existing structure / pipe-to-solid potential records.

vi) Possibility of integration/isolation of CP systems, which may involve negotiations
with owners of other services.

vii) Existing and proposed DC/AC power sources and systems using earth return path
such as HVDC substations/ earthing stations, fabrication yards with electric welding
etc. in the vicinity of the entire pipeline route.

viii) Crossing and parallel running of electrified and non-electrified traction (alongwith
information regarding, operating voltage, AC/DC type etc.) as well as abandoned
tracks near ROW having electrical continuity with the tracks in use.

ix) Crossing or parallel running of any existing or proposed EHV/HV AC/DC overhead
power lines along with details of voltage, AC/DC type etc.

x) Voltage rating, phases, sheathing details of underground power cables along ROW
or in its vicinity.

xi) Any other relevant information that may be needed in designing and implementing
proper cathodic protection scheme for the proposed pipeline. Graphical
representation of existing structure/ pipe-to-soil potential records.

Contractor shall conduct necessary potential gradient surveys for any existing
anode ground beds that may interfere with the CP system of the pipelines covered
under this project.

4.5 Report

On completion of all field work, a report incorporating all the results generated from
surveys and details of additional data collected shall be prepared. The report shall also
contain detailed interpretation of survey results and resistivity data, probable interference
prone areas, selected locations for anode ground beds, etc., to form a design basis for the
scheme of cathodic protection. This report shall also include various drawings prepared in
connection with the above work. Soil resistivity values shall be plotted on semilog graph
sheets.

5.0 CATHODIC PROTECTION DESIGN PARAMETERS

A distinctly independent impressed current cathodic protection system shall be provided to
protect the external surfaces of the complete pipeline/structure installation as specified.

Unless otherwise stated, the following parameters shall be used for design of permanent
cathodic protection system:

5.1 Protection Current Density Range
i) Pipelines having coal tar coating with two/three layers of reinforcement.

<table>
<thead>
<tr>
<th>Pipeline surrounding</th>
<th>Minimum Protection Current Density* (A/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil resistivity 10 ohm m to 100 ohm.m</td>
<td>300</td>
</tr>
<tr>
<td>Soil resistivity less than 10 ohm.m</td>
<td>2000</td>
</tr>
<tr>
<td>Soil resistivity more than 100 ohm.m</td>
<td>200</td>
</tr>
<tr>
<td>Sea Water</td>
<td>5000</td>
</tr>
</tbody>
</table>

* Actual current density to be adopted shall be decided based upon soil and other environmental conditions, current drainage survey data, proximity of foreign pipeline structures and other interference areas affecting the installation. Where considered necessary for satisfactory protection of pipeline the current density shall be suitably increased by contractor. Also refer to clause 7.1 iv) below.

ii) Pipeline having fusion bounded epoxy coating:

<table>
<thead>
<tr>
<th>Pipeline surrounding</th>
<th>Minimum Protection Current Density* (A/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil resistivity 10 ohm m to 100 ohm.m</td>
<td>125</td>
</tr>
<tr>
<td>Soil resistivity less than 10 ohm.m</td>
<td>500</td>
</tr>
<tr>
<td>Soil resistivity more than 100 ohm.m</td>
<td>90</td>
</tr>
</tbody>
</table>

iii) Pipeline having polyethylene coating

<table>
<thead>
<tr>
<th>Pipeline surrounding</th>
<th>Minimum Protection Current Density* (A/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil resistivity 10 ohm m to 100 ohm.m</td>
<td>50</td>
</tr>
<tr>
<td>Soil resistivity less than 10 ohm.m</td>
<td>125</td>
</tr>
<tr>
<td>Soil resistivity more than 100 ohm.m</td>
<td>35</td>
</tr>
</tbody>
</table>

At HDD (horizontal direction drilling) crossing, the pipe protection current density applicable for marshy area shall be considered.

5.2 The pipe protection Current Density indicated in the clause 5.1 above shall be applicable where the temperature of the fluid transported by the pipeline/ the surface temperature of the buried portion of the pipeline does not exceed 30°C. Where this temperature exceeds 30°C, the protection Current Density shall be increased suitably in consultation with the Owner/PMC.

5.3 Safety factor for current density : 1.3

5.4 Anode utilisation factor : 0.85 for centre connected anode.

(For high silicon cast iron anode) 0.6 for end connected anode.

5.5 Anode surface current density : 10 Amp./Sq.m. (max.)

For high silicon cast iron anode
For continuous operation

5.6 Anode consumption rate : 0.2 Kg./Amp.yr.
5.7 Pipeline natural potential : (-) 0.45 V
5.8 Design life of CP System : 30 years
5.9 Anode ground bed loop resistance: 1 ohm (max.).

including anode to ground resistance, anode and cathode cable resistances.

(The output voltage rating of the CPTR unit /CPPSM shall in minimum be adequate to drive the specified end of life cathodic protection current with safety factor, considering the total anode ground bed loop resistance as the sum of the resistance specified in this clause and pipe to earth resistance).

5.10 For mixed metal oxide coated titanium anodes the anode utilisation factor, anode surface current density and anode consumption rate etc. shall be as per the guaranteed values published by the manufacturer and supported by test certificates/ field proven ness.

6.0 CATHODIC PROTECTION DESIGN CRITERIA

Cathodic protection system shall be designed to meet the following criteria :

i) The pipe to soil potential measurements shall be between (-) 0.9V (OFF) and (-) 1.18V (OFF) with respect to a copper/copper sulphate reference electrode.

ii) In rare circumstances, a minimum polarisation shift of (-) 100 millivolts may be accepted as an adequate level of cathodic protection for the pipeline with the approval of Owner.

iii) A positive potential swing of 100 millivolts or more shall be considered sufficient to indicate the presence of an interaction/interference situation requiring investigation and incorporation of mitigation measures by the CONTRACTOR.

7.0 SYSTEM DETAILS

The system shall include the following major equipment/sub-systems unless otherwise specified in project specifications:

- CP stations
- CPTR units/cathodic protection power supply modules (CPPSM).
- Anode ground beds and anodes
- Anode junction box
- Cathode junction box
- Test stations
- Permanent reference cells
- Electrical resistance probes
- Polarisation cell and surge diverter
- Polarisation coupons
- Computerized Test Stations
- CP system at cased crossing
- Cables

All equipment shall be new and procured from approved reputed manufacturers. Equipment offered shall be field proven. Equipment requiring specialised maintenance or operation shall be avoided as far as possible. Prototype equipment shall not be accepted.

All equipment/materials shall conform to the relevant specifications included in the tender document.

All equipment including CPTR unit, CPPSM, test stations, anode lead junction boxes etc. shall be located in safe non-hazardous areas.

Where it is essential to install the equipment in hazardous area, such equipment shall be flame proof type and shall meet the requirement of IS: 2148, 5572 or equivalent international standard and shall be suitable for gas group, temperature class T3 (200°C). Indigenous equipment shall be certified by CMRI or any other recognised testing body and shall be approved by the concerned statutory authority. All flameproof equipment shall carry the BIS license marking as per the requirement of statutory authorities.

All Imported equipment for hazardous area may be tested and certified by an independent certifying agency of country of equipment origin and shall be approved by the concerned statutory authority in India.

7.1 Cathodic Protection Stations

The number and exact locations of CP stations shall be worked out based on the corrosion survey data collected. In addition, the following guidelines shall be followed for selecting the locations:

i) Number of CP stations and their selected locations shall ensure that these remain valid and are adequate for the full design life of the system after considering all foreseeable factors.

ii) As far as possible, the availability of nearby low resistivity areas for location of associated ground beds must be ensured while selecting the locations of CP stations.

iii) As far as possible, locations of intermediate CP stations shall coincide with the locations of SV stations.

iv) The locations of CP stations and anode ground bed current ratings shall be suitably selected. The same shall be verified for adequacy by the contractor. The requisite current drainage tests/survey shall be conducted by the contractor to establish the adequacy of CP current requirement indicated in clause 5.0 above and adequacy of number, ratings of CP stations for permanent CP system selected. The minimum end of life pipe protection current requirement shall be considered as the current requirement indicated in the clause 5.0 above or 3 times the current density value measured by the current drainage survey for polyethylene coated pipeline and 4 times the current density value measured by the current drainage survey for fusion bonded epoxy, coal tar enamel with reinforcement coated pipeline, whichever is maximum.
7.2 CP Transformer Rectifier Unit / CPPSM

The supply, installation, testing and commissioning of cathodic protection power supply module (CPPSM) / indoor type Cathodic Protection Transformer Rectifier Unit (CPTR unit)/ outdoor type CPTR unit installed in kiosk along with kiosk shall be included in contractor's scope. The CP TR units shall be provided at CP stations where reliable AC power supply is available. CPPSM shall be provided at other CP stations where reliable DC power supply instead of reliable AC power supply is available. The CPTR unit / CPPSM shall be installed in nonhazardous (safe) area.

For more details refer: 4002-TS-0823 & 4002-TS-0824

7.3 Anode Ground Beds

i) Each CP station shall have an independent anode ground bed, which may be of shallow or deep well construction depending upon the data collected by the contractor. Deep well ground beds may also be used in the congested locations where availability of suitable land for spread out ground beds is restricted.

ii) Ground bed shall be located electrically remote from the pipeline and foreign pipeline/ other buried metallic structures. Nearest part of the anode bed shall at least be 100 meters away from the pipeline and foreign pipeline/ other buried metallic structures. The anodes installed in the ground shall be located in perennially moist strata, wherever possible. Horizontal ground beds shall be at right angles to the pipeline, as far as possible.

The location of ground bed shall be checked and ensured for remoteness from the pipeline and other buried foreign pipelines/structures, building foundations, switchyards, electrical earthing systems, etc.

iii) Unless otherwise agreed, anodes shall be of mixed metal oxide coated titanium anodes.

iv) Sheet steel anode canisters of adequate size shall be provided for each anode. Anode canisters shall be filled with petroleum coke breeze. In case of deep well ground beds non-canistered anodes with petroleum coke breeze in the well surrounding the anodes shall be provided.

v) Each shallow anode-bed shall contain anodes with canisters positioned horizontally or vertically in the soil with suitable backfill. The depth of anodes (depth of top of anode in case of vertically laid anodes) shall not be less than 2 meter from grade level

vi) Layout of anode installation in anode bed shall be detailed out in drawings showing anode installation details, anode grouping, anode wiring, anode cable routing, etc. The deep well anode ground bed details shall include the details of anodes, deep well casing, anode positioning, anode cable supporting, deep well gas venting, active, passive portions of the ground bed, etc.

vii) Anodes shall be supplied complete with tail cables, which shall be long enough for termination on their associated anode lead junction boxes without intermediate joints. Exact lengths and termination details shall be indicated in construction drawings.

viii) Potential gradient around the anode bed shall be within safety requirements with regard to interference on foreign structures and its effective boundary shall be defined.
ix) In case of two parallel pipelines running in the same ROW, the anode ground beds of the respective pipelines shall be located on the respective sides of the pipelines.

7.4 Anode Junction Box

Depending on the size and configuration of anode ground beds, one or more anode junction boxes shall be provided at each ground bed. All cable tails from individual anodes shall be terminated onto the respective anode junction boxes, which shall be further connected to the main anode junction box (where applicable). The main anode junction box shall be connected to the cable coming from CP power source. Each outgoing circuit in main junction box (where applicable) and each anode circuit in junction shall have provision for measurement and control of individual circuit/anode current.

7.5 Cathode Junction Box

Where output of the CP power supply unit is connected to multiple pipelines a cathode junction box shall be provided near the pipelines at the location of connection of the negative drainage cable to the pipelines.

The negative of the CP power source shall be connected to the incoming circuit of the cathode junction box. The junction box shall have separate outgoing circuit one for each pipeline to collect the negative drainage currents from each of the parallel pipelines.

The incoming circuit shall have a current measurement facility. Each outgoing circuit shall have provision for measurement and control of current.

7.6 Test Stations

7.6.1 Test stations shall be provided along the pipeline ROW for monitoring the performance of the cathodic protection system at the following locations. Test stations shall be provided at additional locations, if required, so that distance between any two adjacent test stations does not exceed 1000 meters in inhabited areas and 2000 meters in uninhabited areas like forest/deserts:

i) At all insulating joints.

ii) At both sides of metalled road crossings.

iii) At vulnerable locations with drastic changes in soil resistivity.

iv) At locations of surge diverters, pipeline grounding through polarisation cells, zinc and magnesium anodes.

v) At EHV/HV AC/DC overhead line crossings and selected locations where EHV/HV overhead line is in the vicinity of the pipeline.

vi) At railway line crossings and at selected locations along lines running parallel to the pipeline.

vii) At both sides of major river crossings.

viii) At EHV/HV cable crossings or along routes where EHV/HV cables are running in parallel.

ix) In the vicinity of DC networks or grounding systems and HVDC grounding systems where interference problems are suspected.

x) At crossings of other pipelines/structures.
xi) At the locations of reference cell, electrical resistance probe and polarization coupon installation.

xii) At the location of computerised test stations.

xiii) At both sides of cased crossings.

xiv) Locations where interference is expected.

xv) At locations of sectionalising valve (SV) stations.

xvi) At any other locations considered necessary by Owner/Owner's representative.

7.6.2 Test stations for bonding shall be provided with shunt and resistor as a means to monitor and control current flow between the pipeline and foreign pipelines or structures that may exist in common ROW.

7.6.3 Test stations with current measuring facility shall be provided at each CP station drainage point (to measure pipeline current on anyone side of pipeline from drainage point at intermediate CP station and towards protected side of the pipeline at starting, end point CP stations), at interference prone areas, on both sides of major river crossings, near marshy areas and minimum one for every 10 km max. along the pipeline.

7.6.4 Test stations shall be installed with the face of the test station facing the pipeline. The nameplate of test stations shall carry the following minimum information:

- Chainage in km.
- Test station connection scheme
- Distance from pipeline in meter.
- Direction of product flow.

7.6.5 Number of terminals and different schemes of wiring shall be as per the test station connection scheme. Minimum twenty percent spare terminals shall be provided in each test station.

7.6.6 Minimum two cables from the pipeline shall be provided at any test station.

7.6.7 The location of all the test stations shall be marked with their connection schemes and other relevant information on alignment sheets. A detailed test-station schedule shall be prepared.

7.7 Permanent Reference Cells

7.7.1 High purity copper/copper sulphate reference cells with proven high reliability shall be provided for stable pipe to soil potential measurement at CP stations, polarization coupons and computerized test station locations along ROW.

7.7.2 Silver/Silver Chloride reference cells in place of copper/copper sulphate cells shall be provided at marshy area locations, where water table is high and chloride concentration is more than 300 ppm. The test station connection scheme shall clearly indicate the type of the reference electrode (Cu CUS04/Ag AgCl) at these locations.

7.7.3 The life of the reference cells shall be minimum 20 years under the installed conditions.
7.7.4 The cable from reference cells shall be provided up to CP power source at CP stations and up to test stations at the locations of polarization coupons, computerised test stations. The cable up to CP power source shall be routed through test stations near pipeline.

7.8 Electrical Resistance Probe

7.8.1 The electrical resistance probes (E/R probes) utilising the electrical resistance technique shall be provided along the pipeline at marshy areas and at vulnerable locations to monitor the external corrosion activity on the pipeline. The lead-wires of the probe shall be connected to pipeline through test station and terminated inside test station enabling periodic resistance measurement of the probe using a portable probe measuring instrument.

7.8.2 The material of the E/R probe element shall be of the same alloy as of the pipeline material. The probes shall be provided preferably at the bottom portion of pipeline.

7.8.3 Sufficient number of E/R probes, the locations of their installation and the number of portable E/R probe reading instruments shall be provided.

7.9 Polarisation Cell and Surge Diverter

7.9.1 Polarisation Cell

i) Where extra high voltage (66 KV and above) transmission line runs in parallel or crosses the pipeline, the pipeline shall be grounded through polarisation cell with zinc galvanic anodes of min. 20 kg net each. Grounding shall be done at regular intervals of maximum 1 km where transmission lines run parallel within 25 metres of the pipeline to control any surges in the pipeline potential that may appear in case of transmission line faults.

ii) Locations along pipeline where continuous induced over-voltage due to EHV/HV line etc. is expected or observed during commissioning, the pipeline shall be earthed through polarisation cell to the earth system of the EHV/HV tower causing the voltage induction or to a separate earthing system of zinc anodes through polarisation cell.

iii) Polarisation cell shall be installed inside test station of suitable size.

7.9.2 Surge Diverter

Explosion proof spark gap surge diverter shall be provided across each insulating joint to protect it from high voltage surges. surge diverters shall be provided for classified areas.

7.9.3 The total system including cables, cable termination, anodes/surge diverters, polarisation cell shall be suitable for the anticipated fault current at the location of installation.

7.9.4 The surge diverter and polarisation cell system shall be suitable for the design life of permanent CP system. The grounding system shall have minimum resistance to earth to restrict the pipeline voltage as per NACE/VDE criteria but shall not exceed 5 ohms.

7.9.5 The anodes shall be pre packed with special backfill adequately so that the performance of the anode is not affected by the carbonates, bicarbonates, nitrates, etc, present in the soil. In any case, the thickness of back fill shall not be less than 50mm on all the sides of the anode.

7.10 Motor operated valves where located on the cathodically protected portion of the pipeline shall be grounded by a zinc anode of 20 kg net. Magnesium anodes grounding, if any, provided during temporary CP system shall be disconnected. The MOV power supply
cable armour shall be insulated (by cutting and taping with insulation tape) at MOV end to avoid armour carrying CP current.

7.11 The above ground cathodically unprotected pipeline at terminals, intermediate SV stations, pigging stations, etc. shall be earthed with GI earth electrodes. The resistance to earth of grounding shall be limited to 5 ohms max.

7.12 **Polarisation Coupons**

The steel coupons of pipeline material shall be provided along the pipeline to monitor the adequacy of the CP system to polarize/protect coating holidays. Coupon shall be installed at CP station drainage points, predicted cathodic protection mid points along the pipeline, at locations where the pipeline is bonded to foreign pipeline/structures, interference prone areas, marshy areas and at other locations such that minimum one coupon is installed maximum every 10 km approximately. Coupons shall be installed at bottom 113rd portion of the pipeline and 250 mm away from the pipe surface.

The coupons shall be constructed from the pipeline material and shall have uncoated surface of 100 mm x 100 mm exposed to soil. Two cables one for connection to pipeline for protection and other for potential measurement shall be provided for each coupon. The protection cable shall be connected through a magnetic reed switch inside the test station to enable measurement of coupon 'OFF' potential.

A permanent reference electrode shall be installed adjacent to the coupon in a manner so as to measure the representative potential of the coupon.

Magnets for operation of reed switch shall be provided.

7.13 **Computerized Test Stations**

Computerized test stations shall be provided along the ROW of the pipeline for automatically monitoring and recording the pipe to soil potential, pipe current, etc. of the pipeline, casing pipeline and foreign pipelines, etc. as required. The computer within the test station shall measure and record these parameters regularly at programmed intervals. The computers shall have required number of input ports for measurement of potentials and current as applicable at the location of its installation. Computers shall have real time clock and record the time of data measurement. Each computer shall an identification number incorporated in its software, which shall be clearly indicated along with the data display/print out.

The computers shall be programmed to collect and store all the field parameters at regular intervals.

Data-retrieval computer of portable type suitable for use in field for programming the field computers and retrieving the data stored by the field computers.

7.14 **CP at Cased Crossing**

7.14.1 At cased crossings where casing is coated, the casing shall be protected by sacrificial anode installations provided at both ends of casing. The anode installation shall be sized based on the permanent C.P. design parameters and design life of permanent CP system. At cased crossings where casing is uncoated or painted, additional protection for casing pipes may not be provided.

7.14.2 The carrier pipe inside the painted or coated casing shall be protected by zinc ribbon anodes weld connected to the outer surface of bottom of carrier pipe extending up to hour
hand positions of 4 and 8 O'clock. The anodes shall be placed at close intervals as per
design calculations with minimum one number of anode installed between every two
supports provided between carrier and casing. The anodes shall be sized based on the
permanent CP design parameters for marshy area and design life of permanent CP
system.

7.14.3 Where casing is uncoated or unpainted additional protection for carrier pipe may not be
provided.

7.15 Reference Cell Access Points

Reference cell access points shall be provided near insulating joint locations and at SV
stations, where the ground is paved, for measurement of pipe to soil potentials. A
perforated PVC pipe filled with native soil and buried at the location shall be provided for
the purpose. The length of the PVC pipe shall be adequate to reach the native soil below
the paving.

7.16 Cables

7.16.1 Cables shall be with annealed high conductivity stranded copper conductor, PVC
insulated, 650/1100 V grade, armoured, PVC sheathed conforming to IS 1554 part-I,
except for the cables for anode tail, reference cells and pipeline for potential
measurements. The size of the copper conductor shall be minimum 35 sq.mm. for anode
and cathode cables, 6 sq.mm. for current measurement, 10 sq.mm. for anode tail cables
and polarization coupon protection cables. The size of cable for bonding, polarisation cell,
grounding anodes and surge diverter connections shall be suitable for the maximum fault
current subject to minimum 25 sq mm.

7.16.2 The anode tail cables shall be PE insulated, 650V grade, unarmoured, PVC sheathed and
length shall be sufficient for termination on anode lead junction box without any joint in
between.

7.16.3 The cables for reference cells, coupon and pipeline potential measurements shall be of 4
sq.mm copper conductor, PVC insulated, Aluminium backed by mylar/polyster tape
shielded, PVC sheathed, armoured, PVC over all sheathed type.

1.16.4 The CPTR unit incomer cable shall be minimum 4 sq.mm. Copper conductor, 650/1100 V
grade, PVC insulated, armoured, PVC sheathed. The cable shall be of 3 core type for
single phase CPTR units and of 4 core type for 3 phase CPTR units.

7.16.5 The cables for connecting various transducers from CPTR unit/CPPSM to telemetry
interface junction box shall be twisted pair with individual pair shielded and overall shielded
with aluminium backed by mylar/polyster tape, PVC sheathed, armoured, PVC over all
sheathed type.

8.0 INSTALLATION

8.1 Cable Laying

i) Cables shall be laid in accordance with layout drawings to be prepared by the
contractor. No straight through joint shall be permitted. Cable route shall be
carefully measured and cables cut to required length. Minimum half metre cable
slack shall be provided near anodes, anode junction box, pipeline and test stations
to account for any settling.
ii) All cables inside station/plant area shall be laid at a depth of 0.75 metre. Cables outside station/plant area shall be laid at a depth of minimum 1.5 metres. Cables shall be laid in sand under brick cover and back filled with normal soil. For cables laid outside the station/plant area, polyethylene warning mats shall be placed at a depth of 0.9 metre from the finished grade, to mark the route. iii) In case of above ground cables, all unarmoured CP cables shall be laid in GI conduits of sufficiently large size, up to accessible height for protecting against the mechanical damage.

iii) All underground unarmoured cables including anode tail cables shall run through PE sleeves. Distant measurement cables and permanent reference cell cables routed along the pipeline shall be carried at the top of the carrier pipe by securely strapping it at intervals with adhesive tape or equivalent as required.

iv) PVC pipes of proper size shall be provided for all underground cables for road crossings.

v) Cables shall be neatly arranged in trenches in such a manner that crisscrossing is avoided and final take-off to equipment is facilitated.

vi) The cables for reference cells and pipeline potential measurement shall be routed in a separate trench other than the trench provided for the rest of the CP system cables, AC cables for CPTR Units etc.

vii) The armour of the cables from CP station to test station (potential measurement, reference cell & drainage cables etc.), CP station to ground bed (anode cable) and test station to pipeline shall be earthed only at CP station end and test station end respectively of the cables. The cable armour shall be insulated (by tapping with insulation tape) to avoid armour carrying CP current.

8.2 Permanent Reference Cells

The permanent reference cells shall be installed in natural soil conditions as per the recommendations of the cell manufacturer. Installations in highly acidic/alkaline soil and soil contaminated by hydrocarbons shall be avoided.

8.3 Cable to Pipe Connections

Connections of all cables other than cathode drainage cables to the pipeline or to charged pipelines shall be made by pin brazing. The resistance of the cable to pipe at the pin brazing connection point shall not exceed 0.1 ohm.

The cathode drainage cable shall be connected to a bolt welded to a metal plate, which is weld connected to the pipeline. The material of the plate shall be same as that of the material of the pipeline.

Pipe coating shall be repaired after connection of cable to pipeline. At cathode drainage point the cable joint including the bolt, metal plate and the exposed portion of the pipeline shall be covered by the coating repair material against ingress of water/moisture. The coating repair material shall be compatible with the original coating and shall prevent ingress of water along the cable surface and at the interface of coating repair with the original pipe coating.

8.4 Ground Bed Fencing

Chain link fencing shall be provided around the location of each ground bed/anode lead junction box.
9.0 FIELD TESTING AND COMMISSIONING

9.1 System testing at site

Field tests as per the reviewed field testing and commissioning procedures prepared by the Contractor shall be carried out on the equipment/systems before these are put into service. Acceptance of the complete installation shall be contingent upon inspection and test results. Field testing shall include but not be limited to the following:

i) Contractor shall carry out pre-commissioning operations after completion of installation of the system including all pre-commissioning checks, setting of all equipment, control and protective devices. All site tests, reliability and performance tests shall be carried out by Contractor.

ii) Before the electrical facilities are put into operation, necessary tests shall be carried out to establish that all equipment and devices have been correctly installed, connected and are in good working condition as required for the intended operation. Owner/Owners representative may witness all tests. At least one week's intimation notice shall be given before commencing the tests.

iii) All tools, equipment and instruments required for testing shall be provided by Contractor.

iv) Generally, the following minimum tests must be carried out and results shall be recorded:

   - Visual Inspection : Comparison with drawings, specifications, detailed physical inspection and, if necessary, by taking apart the component parts.

   - Testing : Simulation tests of equipment

a) Cables

- Cable No.
- Voltage grade.
- Conductor cross section
- Continuity check
- Voltage test.
- Insulation resistance values between each core & earth, between cores (between core and earth for single core cable).

All cables shall be tested by 500 V megger.

b) E/R Probe

- Location/Identification number
- Checking of wiring as per schematics
- Resistance reading of probe
- Installed on top/bottom side of the pipeline

c) Reference Cell
- Location
- Type of cell
- Potential reading
- Installed on top/bottom level of pipeline

d) Insulating joint
- Location
- Pipe to soil potential of both protected and non-protected sides of the insulating joint before and after energisation of CP system.

e) Surge diverter
- Location/identification number.
- Rating
- Type
- Check for healthiness.

f) Polarisation Cell
- Location/Identification number
- Rating
- Check for wiring
- Check standby current drain after CP system energisation. (Current drain with respect to voltage across the cell shall be recorded).
- Details of grounding provided for the polarisation cell.

g) Anode Ground Bed
- Location/Station
- Check for actual layout and compliance with drawings.
- Resistance of each individual anode.
- Current dissipation by each individual anode.
- Total resistance of complete anode bed.
- Mutual interference.

h) Computerised test station
- Location/Identification number
9.2 **CP Commissioning Procedure**

A model commissioning procedure for a three stations CP system of a pipeline is given below for general guidance. Contractor shall develop detailed commissioning procedure as per this guideline.

i) On completion of installation of anode beds and other systems as envisaged in this specification, they shall be individually checked, tested and compared against the agreed specifications and procedure.

ii) Electrical continuity of the entire pipeline shall be verified in conformity with design.

iii) Input resistance of the pipeline at all the drainage points shall be checked and recorded.

iv) All current measuring test stations shall be calibrated and recorded using portable battery, variable resistances, voltmeters, ammeters, etc. as required.

v) Temporary protection facilities provided (if any) which do not form part of permanent CP shall be disconnected from the system & removed unless agreed otherwise.

vi) Anodes provided for grounding at the MOVs on cathodically protected portion of the pipeline shall be disconnected. Sacrificial anode where provided for the protection of the casing pipe at cased crossings shall be disconnected.

vii) The pipeline shall be allowed to depolarize for at least 72 hours after switching 'OFF' the protection (if any) of all other pipelines in the common ROW.

viii) Before the pipelines are put on charge by switching 'ON' any of the CP stations, natural pipeline to soil, casing pipe to soil and coupon to soil potential values at all the test stations of the system (coupon to soil potential at the locations of the coupon installations) shall be measured with respect to Copper/Copper Sulphate half cell.

ix) CP station no.1 shall be energised without put potential adjusted to achieve a maximum pipe to soil potential (PSP) as specified, at the test station nearest to the drainage point. Observations on either spread of protected portion of pipeline and coupons under this CP station shall be taken for PSP values at each of the installed
test stations (coupon to soil potential at the locations of the coupon installations). The pipeline current values across the cross section of the pipeline shall also be determined at all the intended test stations influenced by this station.

x) CP station no.1 shall now be switched 'OFF', CP station no. 3 shall be switched 'ON' and measurement procedure as detailed in clause ix) above shall be repeated.

xi) Similarly CP station no. 1 and 3 shall now be switched 'OFF', CP station no.2 shall be switched 'ON' and measurement procedure as detailed in clause ix) above shall be repeated.

xii) All the CP stations of the system shall be switched 'OFF' and the pipelines shall be allowed to depolarize. All the three CP stations in the system shall then be simultaneously switched 'ON' and PSP values at the drainage points of pipeline shall be brought to a value of maximum PSP as specified and a complete set of observations shall be taken.

Another complete set of pipe to soil and coupon to soil observations shall be taken after lines have stayed on charge for 48 hours. If there are appreciable differences in these observations as compared to those of earlier set, a third set of observations shall be taken after 72 hours. Maximum drainage point protective potentials shall not be allowed to go beyond the maximum PSP values as specified, in any case.

Coupon to soil 'OFF' potential shall be measured at all locations of coupon installations by operation of magnetic reed switch in the test station. The PSP of the coupons shall be within the PSP range specified in clause 6 of this document. The output of all CP stations shall then be so adjusted that the sites of occurrence of least negative protective potentials are not less negative than (-) Q.95V (OFF) and sites of occurrence of the most negative protective potential are not more negative than (-) 1.18V (OFF). A full set of pipe to soil, coupon to soil observations shall again be taken 72 hours after the adjustment of potentials and the protection system shall be left in this state of operation.

xiii) Care shall be exercised to ensure that power supply remains uninterrupted during the period of commissioning. In case of an interruption, the test in progress shall be repeated after allowing time for polarisation. More sets of observations shall be taken in any of the steps specified above, if advised by the Owner/Owner's representative.

xiv) The zinc anodes for grounding of MOVs at the locations of MOVs on cathodically protected portion of the pipeline shall be reconnected to the MOVs.

xv) At cased crossings where casing is protected, sacrificial anodes provided for the casing shall be connected to the casing pipe. The casing to soil potential and anode output current shall be measured and recorded. Where casing pipe protection is inadequate or the output current of the anode is more than the designed current, then additional anodes shall be provided as required.

xvi) PSP values at each of the test stations of the existing pipelines shall be measured, plotted, where existing pipelines run in parallel to the new pipeline, mutual interference situations between the pipelines shall be identified and necessary mitigation measures shall be provided. Interference situations shall also be identified and mitigated by comparing different sets of readings taken at same test stations at different intervals of time under identical conditions where positive potential swing is 100 mV or more.
xvii) Current readings at all the current measuring test stations shall be measured and recorded.

xviii) Where computerized test stations are provided the computer shall be initialized /started to collect and store the field data of potentials, current readings, etc as programmed.

xix) After one month of starting the computers to collect the field data, the data stored by the computers at all the computerized test stations shall be retrieved/downloaded using the field data-retrieving computer. The data shall be analysed with the help of a station main computer.

xx) At the locations of the Electrical resistance probe installations the resistance readings of the probes shall be measured using probe reader.

xxi) Final records of testing and commissioning including graphical representation of final pipe to soil potential readings shall be compiled with interpretation in consultation with Owner/Owner's representative and submitted.

xxii) If any deficiencies are found in the system, the same shall be rectified by the contractor, at no extra cost or time schedule impact, to the complete satisfaction of Owner/Owner's representative. Such deficiencies shall include mitigation of stray current electrolysis and interference problems that may be found existing in the course of testing and commissioning. A set of PSP observations shall also be taken during the peak of the first dry season after commissioning the system into regular operation. Any deficiency found in the protection of the pipeline shall be rectified by the contractor at his own cost.

xxiii) If it is found during commissioning that the sites of occurrence of least negative or most negative protective potentials are less negative than (-) 0.95V (OFF) or more negative than (-) 1.18V (OFF) respectively even after 72 hours of operation, then the drainage point potentials shall be adjusted depending upon anode ground bed currents in consultation with Owner/Owner's representative. In any case, the protective 'OFF' potential values of pipeline and polarization coupons shall not exceed the PSP value range specified in cl. 6 of this document, at any location on the pipeline.

xxiv) The reference cell shall be calibrated minimum once in 24 hours during the commissioning.

xxv) The current dissipated by individual anodes shall be measured from the anode lead junction box and corrected for equal dissipation to the extent possible keeping the total ground bed current same.

10.0 INTERFERENCE MITIGATION

10.1 Investigations shall be made for stray current electrolysis of the pipeline, mutual interference between the pipeline and foreign pipelines/structures, interference on foreign pipelines/structures due to the CP of the pipeline and ground bed, interference on metallic structures which lie in between pipeline and ground bed or near to ground bed, AC induction on pipeline due to overhead EHV/HV lines, interference due to high voltage DC lines, HVDC earthing system, electric traction, etc.

10.2 Measurements including pipe/structure to soil potentials and pipe/structure currents etc. on the pipeline/structure being CP protected and on foreign pipelines/structures, and ground potential gradient etc. shall be made to investigate the current discharge and pickup...
locations. In case of fluctuating stray currents, investigations shall be made continuously over a period of time and if required simultaneously at different locations to find out the stray current source(s). Recorders shall preferably be used for long time measurements.

10.3 Wherever foreign pipelines which may or may not be protected by an independent CP system run in parallel to the protected pipeline, either in the same trench or very near to the protected pipeline and are not bonded to it, investigations shall be performed for current discharge points on both the pipelines.

10.4 Mitigative measures shall be provided depending upon the type of stray current electrolysis/interference. These shall include installation of bond with variable resistor, diodes, installation of galvanic anodes for auxiliary drainage of current, adjustment/relocation (if possible) of offending interference source, provision of electrical shield etc. depending on the type of interference.

10.5 Bonding with foreign pipelines/structures as a mitigation measure shall be provided where the owners of the foreign pipelines/structures have no objection. Otherwise alternative mitigation measures shall be provided. Wherever bonding is provided for mitigation, the bonding resistor shall be adjusted for optimum value for minimum/no interference. Galvanic anodes installed as a mitigation measure shall be adequately sized for the life specified for permanent CP system.

10.6 Where transmission lines cross the pipeline or run in parallel with in or more than 25m from the pipeline, A.C. Voltage measurements shall also be made on the pipeline to find out continuous induction of voltage. In case of the induced voltage being beyond the safe limits, the pipeline shall be grounded to the nearest transmission tower earth system through polarisation cell or to a separate earthing system of zinc anodes of minimum 20 kg net each through polarisation cell.

11.0 CLOSE INTERVAL POTENTIAL SURVEY

Where specified, contractor shall carry out a close interval 'ON'/"OFF" potential survey over the entire length of pipeline by computerised potential logging method and identify the under protected/over protected area, any major coating damage on the pipeline, after the backfilling has been consolidated sufficiently and CP system has stabilized. Contractor shall provide required mitigation measures and rectify the under/over protected zones, identify if any, the major pipeline coating defects, required to be repaired. During the survey the reference cell shall be calibrated minimum once in 24 hours. Detailed procedures for running this survey shall be submitted for review. Additional tests for detailed identification of coating defects shall be conducted by the contractor.

12.0 DEVIATIONS

12.1 Deviations, if any, from this standard shall be clearly indicated in the offer with reasoning.