

WATER SUPPLIES DEPARTMENT
STANDARD SPECIFICATION E-64-01
IMPRESSED CURRENT CATHODIC PROTECTION
TRANSFORMER-RECTIFIER

1. GENERAL

1.1 Scope

This standard specification stipulates the requirements for the design, construction and testing of transformer-rectifiers used for impressed current cathodic protection (ICCP) systems for buried or submarine metallic pipelines. This standard specification does not cover the design and construction of the whole impressed current cathodic protection systems. For those systems employing sacrificial anodes, the technical requirements of such are covered under the latest edition of the Manual of Mainlaying Practice published by Water Supplies Department.

1.2 Standards

The ICCP transformer-rectifier shall be designed in compliance with British Standard BSEN 13636: Cathodic Protection of Buried Metallic Tanks and Related Piping and International Standard ISO 15589-1: Petroleum, Petrochemical and Natural Gas Industries – Cathodic Protection of Pipeline Systems.

1.3 Design of the ICCP Transformer-rectifier

The contractor shall submit design calculation, design criteria and parameters of the ICCP system in accordance with the applicable internationally accepted standards including the National Association of Corrosion Engineer (NACE) recommended practices, British Standards and DNV recommended practices as specified in the specification for the design of the ICCP system. Based on the results of current requirement calculation and transformer-rectifier d.c. output voltage, the Contractor shall recommend the rated output voltage and current of the ICCP transformer-rectifier with recommended operation safety margins for the Engineer's approval. The ICCP transformer-rectifier shall be composed of a power transformer and a rectifier unit complete with automatic control unit/circuitry, associated indication and protection equipment as well as interfacing facilities for remote control and monitoring.

1.4 Site Operating Conditions

(a) Maximum altitude above sea level : 1,000 m

- (b) Maximum ambient temperature : 35°C Average over 24 hours
40°C Peak over any 4 hours
- (c) Minimum ambient temperature : 0°C
- (d) Average yearly temperature : 30°C
- (e) Maximum relative humidity : 98 %

2. TRANSFORMER-RECTIFIER UNIT

2.1 General

The transformer-rectifier unit (TRU) shall be oil or air cooled, continuously rated and self-contained. The TRU shall be of solid state type and shall comprise a power supply transformer, rectifier, monitoring equipment, alarm detection equipment, output load voltage/current control equipment and accessories.

The incoming a.c. power supply shall be protected for short-circuit or overload by fuses or circuit breakers and residual current device to BS4293 in accordance with the manufacturer's requirement.

The mains transformer shall be double wound in accordance with BS171, continuously rated and suitable for connection to the 50Hz 380V 3-phase or 220V 1-phase mains supply with a voltage and frequency variation of $\pm 6\%$ and $\pm 2\%$ respectively. For air cooled TRUs, the transformer shall have Class H insulation.

The rectifier shall be bridge connected for full wave rectification, continuously rated at maximum current over the whole voltage range, and provided with suitable protection against power line surges. It shall employ the latest thyristor/diode technology to offer good performance and reliability. For standard constant voltage units, on load voltage control shall be provided by power electronic devices with a controlled output range from 5% to 100% of the rated d.c. output voltage with an output ripple not exceeding 5%.

The TRU shall possess the following electrical characteristics and facilities :-

- (a) Output DC Voltage : To be rated at least 120% of the calculated output nominal voltage
- (b) Output DC Current : To be rated at least 120% of the calculated output nominal current
- (c) Transformer efficiency : More than 95% at full load output
- (d) Overall TRU efficiency : More than 80% and 65% at full load output

for three phase and single phase design respectively;

- (e) Power factor : Better than 85%
- (f) Insulation level : 2 kV
- (g) Peak inverse voltage of diodes/SCRs : 2 kV
- (h) Output voltage ripple : Less than 5% at rated output
- (i) Lightning protection : To be provided on both input and output circuits

The units shall provide automatic control for constant voltage, constant current and preset protected potential of the pipeline against referenced electrode controlled as the design of the cathodic protection system requires. Generally, the transformer-rectifier output voltage shall not exceed 50V d.c..

Ventilation fans shall be used for TRUs rated above 6 kVA. TRUs rated below 6kVA shall be designed for natural ventilation with an ambient temperature of up to 40°C. Components shall be rated for continuous operation at not lower than 55°C.

3. ICCP TRANSFORMER-RECTIFIER PANEL

3.1 Panel Construction and Equipment Layout

The transformer and rectifier of the TRU shall be accommodated in one or two panels, depending on the equipment ratings, made of 2.5mm thick sheet steel. For panels exceeding 750mm in width, double-leaf doors shall be provided. If the transformer and the rectifier are accommodated in separate panels, the panel heights shall be equal. The panels shall be designed for front access with full length lockable swing doors made of 2.5mm thick sheet steel. The sheet steel of the panels shall be suitably braced to form rigid structures designed for a protection rating of IP54 or better to IEC 60529, suitable for wall or floor mounting as applicable. A plexiglass viewing window on the panel doors shall be provided to allow the meters to be read without opening the transformer rectifier unit. Panel covers shall have return flanges fitted with gaskets. The design of the panels shall allow adequate ventilation. A detachable cable gland plate and suitable terminals for cable connection shall be provided.

3.2 Surface Treatment and Paint Finish

The surface treatment and paint finish of panels shall be suitable for use under the possible corrosive environment associated with seafront installation. The fabricated

structure shall receive appropriate surface treatment prior to painting with epoxy powder coating. The exterior colour of the panels shall be grey to BS4800, Shade 18B21 or equivalent and the interior colour of the panels shall be white.

3.3 Rating Plate

A stainless steel rating plate with engraved lettering shall be provided on each TRU panel. The rating plate shall indicate the rated a.c. voltage, current, frequency, power and power factor, and the rated d.c. output voltage and current rating.

3.4 Anti-condensation Heater

For each panel and cubicle where condensation is likely to be present, an anti-condensation panel heater complete with a humidity sensor and 16A double-pole isolating switch shall be fitted to each separate enclosure.

3.5 Power Supply

Mains supply to TRU with output below 1kW, power supply input shall be 1-phase 220V 50Hz, while TRU of over 6kW output, power supply input shall be 3-phase 380V 50Hz nominal. For TRU with output rating between 1kW and 6kW, the mains supply shall be either 1-phase or 3-phase as specified in the Particular Specification. Where 3-phase power supply is used, the 'mains on' lamp shall only be lit just when all 3-phase voltages are under healthy condition.

Suitable harmonics suppression devices shall be provided to limit the total odd harmonic current distortion to the power source to within 20%.

3.6 Mode of Operation

The control modes shall enable the cathodic protection current to be adjustable so that the appropriate protection potential on the protected water pipe close to a preset value is achieved and maintained. Meanwhile, the output current shall be kept close to the minimum needed for the designed cathodic protection. The d.c. output control shall be capable of operating in the following modes selectable by the operator.

(a) Auto Reference Mode

Under this mode of operation, TRU voltage and current output shall be automatically controlled by feedback on the water pipe potential against the reference electrode. The TRU shall automatically maintain the water pipe potential to within 1.5% of the preset value.

(b) Automatic Voltage Current Control Mode

The operation of the TRU under this Automatic Voltage Current Control (AVCC) mode shall be capable of operating in either Constant Voltage Mode or Constant Current Mode.

In Constant Voltage Mode, the d.c. output voltage shall be adjustable from zero to the rated value in a stepless manner by means of a voltage setting potentiometer.

In Constant Current Mode, the d.c. output current shall be adjustable from zero to the rated value in a stepless manner by means of a current setting potentiometer.

For both modes, the unit shall be capable of maintaining the voltage and current regulation within 1% over the for a.c. supply voltage variation of $\pm 10\%$ and load variation from 0 to 100%.

4 TRU PROTECTIVE EQUIPMENT

4.1 General

Unless otherwise specified, the load shall not be disconnected automatically from the TRU in the event of a failure of the mains supply, the power transformer or the rectifier.

Current limiting circuitry shall be incorporated in both the power transformer output and the rectifier output to prevent damage to the TRU, in case of a short-circuit, overload or accidental polarity reversal.

An earth leakage detector shall be provided for the rectifier output to detect the current leakage from either the positive or the negative terminal. An alarm shall be initiated and relayed to the control centre for remote monitoring.

HBC fuses shall be provided at the mains input and at the rectifier output. Each fuse holder shall be provided with a label indicating the fuse rated current and application.

5 MONITORING AND CONTROL EQUIPMENT

5.1 Monitoring and Control Functions

The TRU panel shall be equipped with a control and remote monitoring unit/circuitry, which shall provide the control modes as described in Clause 3.6 above as well as the following functions and features for remote monitoring and control :-

- (a) Compatibility with wide range of communication protocols including serial RS485, TCP/IP/Ethernet or fieldbus interface for remote monitoring of operational conditions and alarms, where a PLC type control unit is installed.
- (b) Capable of connecting and accepting up to the number of installed reference electrode inputs required by the cathodic protection system and automatically taking reference on the reference electrode to supply the protective potential to the water pipe at a pre-selected value, e.g. within the range of -800mV to -1,100mV, which is more negative than the natural potential of the water pipe to be protected.
- (c) A timer and a test button, or alternatively by touch screen display mimics, shall be provided to switch the power output of the TRU on and off in ON-Off cycles so as to facilitate measurement of instant-off potential of the protected pipe against a portable copper-copper sulphate reference electrode or silver-silver chloride reference electrode at the test station with an AVO meter. The setting range of the timer shall be appropriate to allow measurement of the instant-off potential of the protected water pipe.
- (d) At each current output terminal, a calibrated DC shunt resistor of 0.01 ohm shall be installed to facilitate measurement of current output to the pipe and each anode with a portable AVO meter as well as a voltage detecting circuit for remote monitoring.

5.2 Panel Mounted Indicating and Control Equipment

The following equipment shall be flush mounted on the cubicle/panel for control and monitoring of the cathodic protection system :-

- (a) Mains ON/OFF switch (key lockable)
- (b) AUTO REFERENCE MODE/AUTOMATIC VOLTAGE/CURRENT CONTROL MODE manual selector (key operated)
- (c) Ammeter, TRU output current; scale 0 - 120% of current limit.
- (d) Voltmeter, TRU output voltage; scale 0 - 120% voltage limit,
- (e) Voltmeter, pipe-to-reference electrode potential; 0 to -1.5 V d.c. (or as specified in Particular Specification)
- (f) LED indicating lamps for the following operation conditions :-
 - (i) AC Supply ON indicator for each phase
 - (ii) Unit in Auto Reference Mode
 - (iii) Unit in AVCC Mode
 - (iv) Under-protection

- (v) Over-protection
 - (vi) Reference Electrode Failed
 - (vii) Current Limit Mode (Overcurrent)
 - (viii) AC Supply Under-voltage
 - (ix) AC Supply Phase Fail
- (g) Lamp test push button

Digital type ammeters and voltmeters with an accuracy class of 1.5 and 1.0 to IEC 60051 respectively shall be provided. Alternatively, use of touch screen microcomputer with PLC control for the above alarm and monitoring functions shall also be acceptable.

5.3 Alarm Detectors

Devices for detecting the alarm conditions as shown on Clause 5.2 (f) above shall be provided for initiating of remote alarm and visual display shall be provided.

5.4 Remote Alarms and Indication

Terminals and volt-free changeover contacts for connection to telemetry equipment for transmission of the operation status and alarm signals for remote monitoring shall be provided. Alternatively, providing a fieldbus connection port of a PLC control unit for connection with telemetry equipment is also acceptable subject to the approval of the Engineer.

6. INSPECTION AND TESTING

6.1 General

Where specified in the Particular Specification, an Independent Inspection Body (IIB) shall be nominated by the Contractor and approved by the Engineer to carry out inspection of the ICCP transformer-rectifier panel and to witness tests at the manufacturer's works. The Contractor shall inform the IIB at least seven days before the intended date for the tests and provide him with a complete set of drawings approved by the Engineer.

6.2 Acceptance Test Requirements

6.2.1 Physical Inspection

The following features of the ICCP transformer-rectifier shall be checked for compliance with the Specification and the approved drawings:

- (a) Dimensions
- (b) Construction, finish and quality
- (c) Rating markings
- (d) Components integrity

6.2.2 Performance

The ICCP transformer-rectifier shall be tested for performance at the manufacturer's works. The following routine tests shall be carried out and the certificates/documents are to be furnished by the Contractor before shipment of the equipment.

- (a) Efficiency test and harmonic analysis of the TRU at 25%, 50%, 75% and 100% of the rated output current. Efficiency test of the transformer alone at 100% rated current.
- (b) Heat run test for maximum temperature rise of TRU transformer windings and the power electronic components of the rectifier unit at 100% rated current.
- (c) Insulation resistance test at 2kV between primary and secondary side, primary side and earth, secondary side and earth for the TRU.
- (d) The automatic current control mode of TRU by varying the output voltage at 25%, 50%, 75% and 100% of the rated output voltage at the rated output current.
- (e) The current limiting feature of the TRU by short-circuiting the output terminals of the TRU and setting the maximum current limits at 25%, 50%, 75% and 100% of the rated output current.
- (f) The Auto Reference Mode under different simulated reference voltage.
- (g) Accuracy of all ammeters and voltmeters.

6.3 Site Commissioning Test

A site commissioning test on the ICCP transformer-rectifier shall be conducted by the Contractor to verify that the operation of the TRU shall be in full compliance with the design of the ICCP system under different modes of operation with verification of the measured voltage between the protected water pipe and the reference electrode at all the test stations constructed at site.