400 kV, 275 kV and 220/110 kV Transformers Functional Specification

XDS-GFS-37-001-R0

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EirGrid

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				EirGrid	System Integrity		
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1 Scope

This Functional Specification, together with the accompanying Technical Schedules[1], defines requirements for the following types of transformers for use on the Irish transmission system:

- 400/110 kV
- 400/220 kV
- 220/110 kV
- 275/220 kV

In addition to the requirements of this specification, the transformers shall comply with:

- EIRGRID Functional Specification XDS-GFS-00-001 "110/220/400 kV Substation General Requirements", and other applicable EIRGRID requirements including but not limited to those listed in clause 4.1.

Project specific requirements including the project functional specification, project protection specification and single line diagram.

2 Abbreviations

Table 1 Abbreviations

AIS	Air Insulated Switchgear
AISI	American Iron and Steel Institute
ASTM	ASTM International (formerly known as American Society for Testing and Materials)
BIL	Basic insulation level
BNC	Bayonet Neill-Concelman Connector
BSP	British Standard Pipe
CLP	Classifying, labelling, packaging regulation
CMS	Condition Monitoring System
CPR	EU Construction products regulation
CT	Current transformers
DGA	Dissolved Gas Analysis
EN	European standard
FO	Fibre optics probes
FRA	Frequency Response Analysis
GIC	Geomagnetically Induced Currents
GIS	Gas Insulated Switchgear
HV	High voltage
I.S.	Irish Standard

[1] All references to Technical Schedules within this document refer to XDS-GTS-37-001. The Customer shall submit a completed set of Technical Schedules for EIRGRID approval. For the purpose of this specification the term Customer shall refer to any party (Independent Power Producers, Demand Customers, Transmission Asset Owner, or other developers) or parties working on behalf of (Supplier, Manufacturer, Vendors or Contractors) the Customer responsible for the supply, manufacturing, design and/or build of assets for connection to the Irish Transmission System.

IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
LIC	Rated lightning impulse withstand voltage level
MCB	Miniature Circuit Breaker
MOV	Metal Oxide Varistor
MOSA	Metal Oxide Surge Arresters
MTBF	Mean Time Between Failure
NER	Neutral Earth Resistor
NEX	Neutral Earth Reactor
NDT	Non-Destructive Testing
ODAF	Oil Directed Air Forced
OEM	Original Equipment Manufacturer
OFAF	Oil Forced Air Forced
OLTC	On Load Tap Changer
ONAF	Oil Natural Air Forced
ONAN	Oil Natural Air Natural
PCB	Polychlorinated Biphenyl
PD	Partial Discharge
PVC	Polyvinyl Chloride
REACH	Registration, Evaluation, Authorization and Restriction of chemicals
RIP	Resin Impregnated Paper
RIS	Resin Impregnated Synthetic
ROHS	Restriction Of Hazardous Substances directive
RUSCD	Reference unified specific creepage distance
SF6	Sulphur Hexaflouride
SI	Statutory instrument
SLD	Single Line Diagram
TAO	Transmission Asset Owner
TD	Technical Declaration / Schedule
UHF	Ultra-High Frequency
VT	Voltage transformers
WEEE	Waste electrical and electronic equipment
ZPS	Zero phase sequence

3 Health and Safety

The Customer shall ensure that a satisfactory safety risk assessment in accordance with the EIRGRID Safe by Design methodology has been completed.

General Health and Safety requirements are outlined in XDS-GFS-00-001.

All works are subject to health and safety legislation outline in clause 4.

Refer to clause 8 for requirements relating to materials which may be classified as hazardous.

Asbestos shall not be used in any gasket materials, nor in any other part of the transformer.

Oil shall be certified to contain less than 1 ppm of Polychlorinated Biphenyl (PCB).

The transformer design shall ensure the safety of personnel during installation, operation and maintenance.

Requirements to work at height shall be minimised as far as possible. All meters, dials, access points etc. shall be readable or accessible from ground level. Where working at height is unavoidable, suitable restraints and/or fall arresters shall be incorporated into the design.

All electrical equipment and cabinets required to be accessed for maintenance shall be capable of being earthed.

Suitable safety screening shall be provided for all moving parts (e.g. OLTC drive).

The transformer design shall ensure the safety of personnel during installation, commissioning, operation, inspection and maintenance. The overall risk presented by the hazards shall be evaluated based on the recommended inspection and maintenance intervals recommended by the Customer. Measures to ease the severity of the risk or elimination of the hazard shall be considered in the risk assessment. All necessary safety precautions to be observed by personnel involved in the activities above shall be detailed in the risk assessment. Material Risks shall be identified by the Customer and agreed with the EIRGRID. If other material risks are identified after production of the equipment, then it shall be the Customer's responsibility to rectify such problems.

A material risk assessment conducted with the EIRGRID shall also be required following production of the transformer and shall include the points below and any other areas relevant for the installation, operation and maintenance of the equipment. In particular it shall cover what risks to staff and public arise from use of the transformer design proposed and how these have been mitigated in the design or installation.

The design shall:

(a) Ensure safety of personnel during the operation and maintenance including access to the top of the tank.

(b) Ensure all parts of the main circuits to which access is required or provided shall be capable of being earthed.

(c) Determine the number and location of earthing devices in accordance with the equipment layout, so that the safety of personnel is fully guaranteed during operation and maintenance of the equipment

(d) Provide adequate safety screens for all moving parts.

(e) A person standing on the ground at any accessible location in close proximity to the transformer should have a minimum distance of 2.9 m between the position of their feet and any unscreened live gear.

(f) Tank projections should not constitute climbing aids.

(g) A temporary guard rail system shall be provided which can be readily erected. The tank roof shall be fitted with permanent socket-type mountings for this purpose. The erected rail shall be 0.95 – 1.2 m in height and shall not interfere with access to the transformer fittings and accessories. All position indicators, mechanism boxes, terminal boxes, etc. shall be accessible from ground level with the exception of the diverter switch tap position indicator and other tank-top devices.

4 Legislation Codes and Standards

Equipment offered shall be compliant with the provisions of the latest applicable versions of all relevant Irish legislation and directives of the European Communities.

These include the following or latest versions/ amendments as appropriate:

Table 2 Irish legislation and directives of the European Communities

Number	Title
SI No. 132	Safety signs regulations 1995 (implements EEC Directive 92/58)
SI No. 291	Safety, Health and Welfare at Work (Construction) Regulations
SI No. 299	Safety, Health and Welfare at Work (General Application) Regulations 2007
SI No. 445	Safety, Health and Welfare at Work (General Application) (Amendment) Reg. 2012
Reg (EC) No 1907/2006	Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), Council of 18 December 2006 and any amending legislation
Reg (EC) No 1272/2008	Classification, Labelling and Packaging of Substances and Mixtures (CLP)
Reg (EU) No 517/2014	Fluorinated greenhouse gases and repealing regulation (EC) No 842/2006
Reg (EU) 2015/2068	Format of labels for products and equipment containing fluorinated greenhouse gases
Reg (EU) 2015/2065	Format for notification of the training and certification programmes of the Member States
Reg EU 2015/2066	Minimum requirements and the conditions for mutual recognition for the certification of natural persons carrying out installation, servicing, maintenance, repair or decommissioning of electrical switchgear containing fluorinated greenhouse gases or recovery of fluorinated greenhouse gases from stationary electrical switchgear
Directive 2011/65/EU	Restriction of the use of certain hazardous substances in electrical and electronic equipment (ROHS), RoHS directive (2002/95/EC, 2011/65/EU)
Directive 2012/19/EU	Waste electrical and electronic equipment
Directive 2014/30/EU	Harmonisation of the laws of the Member States relating to electromagnetic compatibility
ECE/TRANS/275	Vol. I and II ("ADR 2019") European Agreement Concerning the International Carriage of Dangerous Goods by Road
Directive 2014/30/EU	EMC compliance
IEC 62271-1: (Ed.1.0) 2017	Clause 7.9.1.2 EMC Requirements
(EU) No 548/2014	Implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to small, medium and large power transformers.

Unless the Customer can show to EIRGRID's satisfaction that CE marking is not required, equipment shall carry the CE Mark in accordance with Directive 768/2008/EC and the EU Construction Products Regulation (No. 305/2011 – CPR) and adequate documentation to demonstrate full compliance shall be retained.

In order to prove compliance, the equipment shall carry the CE Mark in accordance with Direction 768/2008/EC and the EU Construction Products Regulation (No. 305/2011 – CPR) where required.

It is anticipated that transformer itself will not have a CE mark. However, the various components, fans, pumps, etc. should all be CE marked.

In addition, there shall be compliance with the provisions of all relevant Directives of the European Communities relating to work equipment, i.e. in regard to safety of personnel who operate and maintain the equipment.

4.1 EirGrid Standards and Drawings

This specification, and related EIRGRID specifications, including those listed below, specify additional requirements and choices and take precedence in case of conflict with international or national standards.

Table 3 Applicable EIRGRID Standards

Standard Number	Standard Title
XDS-GFS-00-001	110/220/400 kV Substation General Requirements
XDS-GFS-06-001	110/220/400kV Control, Protection and Metering
XDS-GFS-07-001	Station Control and Protection Cabinets and Marshalling Kiosks
XDS-GFS-08-001	Station Auxiliary Power Supplies
XDS-GFS-10-001	Station 220V/48V/24V DC and 230/400V AC Distribution Boards
XDS-GFS-12-001	Earthing and Lightning Protection
XDS-GFS-17-001	Galvanised Fabricated Steelwork
XDS-GFS-18-001	Specification for the hot-dip galvanising of iron and steel other than wire.
XDS-GFS-20-001	Pre-commissioning Requirements
XDS-GFS-333-001	AIS Transformer Neutral Earth Switches
XDS-GFS-35-001	Instrument Transformers
XDS-SDM-00-001	Safe by Design Methodology
XDS-GGD-00-001	Derogation Process Guidance Document
XDS-DGS-00-004	Earthing Practice

4.2 National International and Other Applicable Standards

The transformers shall comply with the latest editions of the international standards, codes and normative references indicated below, and the latest editions of the standards that they reference.

Where a particular subject is not covered by one of the above international standards then a recognised national standard shall apply.

Except where otherwise stated in the functional specification, materials shall be designed, manufactured, tested and installed according to relevant IEC/EN standards. Where applicable the Irish adaptation of the standard (IS EN version), including any national normative aspects, shall apply. Where no IEC standard has been issued to cover a particular subject then an EN, International or British Standard shall be applied. The latest edition and amendments shall apply in all cases. Where no IEC/EN standards have been issued to cover a particular subject, a recognised international standard shall be applied.

Table 4 International Standards

Number	Standard Description
S.R. 61936-1: 2019	Guidelines on the application of I.S. EN 61936-1:2010&A1:2014, Power installations exceeding 1 kV A.C. - Part 1: Common rules
IS 10101 2020+AC1:2020	National Wiring rules for electrical installations
ASTM D 3455	Standard test methods for compatibility of construction material with electrical insulating oil of petroleum origin
ASTM D 2247-15: 2015	Standard Practice for Testing Water Resistance of Coatings in 100 % Relative Humidity
ASTM D 2794-93: 2019	Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)
ASTM D3359-17: 2017	Standard Test Methods for Measuring Adhesion by Tape Test
ASTM D 3363-05: 2011	Standard Test Method for Film Hardness by Pencil Test
ASTM D 4752-20: 2020	Standard Practice for Measuring MEK Resistance of Ethyl Silicate (Inorganic) Zinc-Rich Primers by Solvent Rub
IEC 50629	Energy Performance of Large Power Transformers (u[m] > 36 kV or S[r] >= 40 MVA)
IEC 60076: 2020	Power Transformers all parts
IEC 60060: 2020	High voltage test techniques - all parts
IEC 60068	Environmental testing - all parts
IEC 60137	Insulated bushings for alternating voltages above 1000 V
IEC 60214-1	Tap-changers Part 1: Performance requirements and test methods
IEC 60214-2	Tap-changers Part 2: Application guide
IEC 60227	Polyvinyl Chloride insulated cables of rated voltages up to and including 450/750 V
IEC 60507	Artificial Pollution Tests on High-Voltage Insulators to be used on A.C. Systems
IEC 60529	Degrees of Protection provided by Enclosures (IP Code)
IEC 60567	Guide for the Sampling of Gases and of Oil from Oil-Filled electrical equipment - Sampling of gases and of oil for analysis of free and dissolved gases
IEC 60599	Mineral Oil-Impregnated Electrical Equipment in Service – Guide to the Interpretation of Dissolved and Free Gases Analysis
IEC 60599 AMD 1	Amendment 1 Mineral Oil-Impregnated Electrical Equipment in Service – Guide to the Interpretation of Dissolved and Free Gases Analysis
IEC 60641-2	Pressboard and Press paper for electrical purposes, method of tests
IEC 60688	Electrical measuring transducers for converting A.C. and D.C. electrical quantities to analogue or digital signals
IEC TR 60616	Terminal and Tapping Markings for Power Transformers
IEC TS 60815	Selection and dimensioning of high-voltage insulators intended for use in polluted conditions

Number	Standard Description
IEC 61850	Communication Networks and Systems in Substations
IEC 62271-1	Common specifications for high-voltage switchgear and control gear standards
IEC 62271-209	High-voltage switchgear and control gear Part 209: Cable connections for gas-insulated metal-enclosed switchgear for rated voltages above 52 kV – Fluid-filled and extruded insulation cables – Fluid-filled and dry-type cable terminations – Edition 1.0.
IEC TR 62271-301	High-voltage switchgear and control gear Part 301: Dimensional standardisation of high-voltage terminals
IEC TR 60815	Guide for the Selection of Insulators in Respect of Polluted Conditions
IEC TS 61639	Direct connection between power transformers and gas-insulated metal-enclosed switchgear for rated voltages of 72.5 kV and above-First Edition
IEC 61672	Electroacoustics - Sound Level Meters.
IEC 62535	Insulating liquids - Test method for detection of potentially corrosive sulphur in used and unused insulating oil.
IEC 60296	Fluids for electrotechnical applications - Unused mineral insulating oils for transformers and switchgear
IEC 62474	Material declaration for products of and for the electrotechnical industry
IEC Guide 113	Materials Declaration Questionnaires - Basic Guidelines - Edition 1.0
ISO 12944	Corrosion Protection of Steel Structures by protective paint systems
ISO 2409	Paints and varnishes. Cross-cut test
ISO 2813	Paints and varnishes. Measurement of specular gloss of non-metallic paint films at 20 °, 60 ° and 85 °
ISO 4892-3	Plastics. Methods of exposure to laboratory light sources. Fluorescent UV lamps
ISO 7724	Methods of test for paints. Determination of colour and colour difference: calculation
ISO 9227	Corrosion tests in artificial atmospheres. Salt spray tests
BS EN ISO 25817	Arc-welded joints in steel
Doble TOPS	Transformer Oil Purchase Specification.

Where a particular subject is not covered by one of the above standards then a recognised (in order of preference) European, Australian, Canadian, US or Japanese national standard shall apply.

The Customer shall provide reliability/ MTBF statistics for their transformers per CIGRE TB642 Transformer Reliability Survey WG A2.37.

This specification shall take precedence in case of conflict between it and any of the listed standards, including any of the standards listed above.

4.3 Mean Time Between Failures and Safety Integrity Level Definition

Clause 3.3 above requires the Customer to provide reliability / MTBF statistics for their power transformers per CIGRE TB642 Transformer Reliability Survey WG A2.37. The MTBF of HV and EHV power transformers, should be calculated on the base of failures data related to the period from 2012 till 2022 according to 'high demand mode' as per IEC 61508-1 Tab. 3 (2010).

As per CIGRE, failures are classified into failure location, failure causes and failure modes:

(A) The failure modes to be considered are:

1. Failures that caused fire or explosion (F&E).
2. Major Failures (MaF)
   A major failure was defined as any situation which required the HV and EHV power transformers to be removed from service for a period longer than 7 days for investigation, remedial work, or replacement. The necessary repairs should have involved major remedial work, often requiring the HV and/or EHV power transformers to be removed from its installation site and returned to the factory. A reliable indication that the HV and/or EHV power transformers condition prevents its safe operation is considered a major failure if remedial work (longer than 7 days) was required for restoring it to the initial service capability.
3. Minor Failures (MiF)
   Failure of equipment other than a major failure or any failure, even complete, of a constructional element or a sub-assembly which does not cause a major failure of the equipment.

(B) Failure cause referred to the cause of failure in the primary location where the failure was initiated, and was defined as the circumstances during design, manufacture or application that led to the failure.

(C) According to IEEE [69], failure mode refers to the manner in which a failure occurred, and was categorised as electrical, thermal, and mechanical and contamination.

Failure rate [λ] has been the most utilised measure of reliability because it is based on the count of the number of failures which should be obtainable;

$$\lambda = \frac{n_1 + n_2 + \ldots + n_i}{N_1 \cdot T_1 + N_2 \cdot T_2 + \ldots + N_i \cdot T_i} \cdot 100\%$$

n_i = Number of failures by i-th population
N_i = Number of transformers of i-th population
T = Reference Period of i-th population

The MTBF corresponds to probability of failure [λ] according to formula:

$$MTBF = \frac{1}{\lambda}$$

where MTBF is mean time between failures, which is defined as total working time of produced product for dedicated time period divided by the sum of failures occurred during this period and is calculated accordingly.

The average probability of a dangerous failure on demand of the safety function (PFD_{avg}), gives the probability of failure occurring at any specific time. Its units are failure/item-time. As a result, during time interval T_i , a PFD_{avg} - average probability of a dangerous failure is defined as:

$$PFD = \frac{1}{Ti} * \frac{\Delta n(t)}{Ni}$$

$\Delta n(t)$ = Number of failures in time interval

T_i = Length of time interval (10 years)
N_i = Number of transformers of population in time interval

Safety integrity level (SIL) calculated according to IEC 61508-1 Tab.3, corresponds to probability of a dangerous failure (PFD) according to table;

Safety integrity level (SIL)	Average probability of a dangerous failure on demand of the safety function (PFD_{avg})
4	$\geq 10^{-5}$ to $< 10^{-4}$
3	$\geq 10^{-4}$ to $< 10^{-3}$
2	$\geq 10^{-3}$ to $< 10^{-2}$
1	$\geq 10^{-2}$ to $< 10^{-1}$

IEC 61508 and ISO 13849 define several levels for the level of the "failure probability" of a safety function, the scales covering slightly different areas.

Not more than one dangerous failure of the safety function in	Safety integrity level (SIL) IEC 61508
1 year	-
10 years	SIL 1
100 years	SIL 2
1,000 years	SIL 3
10,000 years	SIL 4

The Customer shall supply details of failures, failure rates and current calculated SIL level as shown above to demonstrate service experience as requested by Clause 3.3 above and evidence of continuous experience and improvement. Evidence of failures in past periods can provide assurance of learnings, design and quantity process improvement of the manufacturer per ISO 9000 management system processes as required.

5 Service Conditions

All transformers shall be designed and constructed to endure service and environmental conditions appropriate to their location and in accordance with the service conditions described in XDS-GFS-00-001 “110/220/400 kV Substation General Requirements”. Transformers will be installed less than 1,000 m above sea-level.

The humid salty atmosphere in Ireland is particularly severe on non-galvanised ferrous parts and on aluminium and its alloys.

6 Service Experience

The Contractor shall comply with each of (1), (2a), (2b), (4),(5), (6), (7), (8) and (9) below. Note point (3a) and (3b) may be considered by the Employer as alternative to (2a) and/ or (2b).

The Contractor shall have:

1) Ongoing experience for at least the past 10 years from the date of this tender in the production of the required range of HV and EHV Power Transformers in the voltage range (220 kV) as specified or higher.
2) Satisfactory[2] Service experience of HV and EHV Power Transformers, in the voltage range from 220 kV and higher:
    a) in utilities in at least three separate countries from the following list – EU, UK, USA, Canada, Norway, Switzerland, Japan, Australia, New Zealand, South Korea, Bahrain, Kuwait, Oman, Saudi Arabia, and the United Arab Emirates with proof of service experience in writing from these Utilities and acceptance of these by the Employer.

AND

    b) with a minimum of 100 transformers in total in these Utilities EACH of which shall have a minimum of five years satisfactory service experience at date of this enquiry issue. Relevant service experience in Irish and other Utilities not referenced in tender submission may be used by the Employer in the evaluation of this criterion at their discretion.
3) If a transformer manufacturing plant, that has supplied transformers meeting the criteria 2(a) and 2(b), cannot meet the specified lead times and required quantities as stated in the enquiry letter due to production constraints, then the Employer may consider transformer offers from an alternative transformer manufacturing plant subject to:
    a) Manufacturing plant is Contractor owned and/ or operated.

AND

    b) Manufacturing plant has supplied a minimum of hundred (100) HV and EHV Power Transformers, in the voltage range from 220 kV as specified and higher to three Utilities worldwide and a minimum of fifty (50) of these transformers shall be in Countries named in 2(a) above. EACH of the fifty (50) units shall have a minimum of five years satisfactory service experience at date of this enquiry issue.
4) The transformers on offer in compliance with this specification shall be manufactured in the same plants which produced the transformers cited as meeting the service experience requirements outlined in 2(a) and 2(b) or 3(a) and 3(b) above.
5) At least 5 years production of HV and EHV Power Transformers in the particular manufacturing plant proposed for this enquiry is required, although if the particular plant proposed is a relocated existing plant using substantially the same workforce, the combined time of both plants would be considered.
6) Acceptance by the Employer of any factory listed during the Tendering Process shall be subject to a detailed Factory Quality and Production Audit by the Employer and/ or its representative.
7) The contractor shall provide evidence of compliance with ALL relevant sections of chapter 0 of this specification. The evidence will be accepted by the Employer subject to confirmation in writing from reference Utilities and acceptance of these by the Employer.
8) The transformers on offer shall comply with service experience requirements of the Corrosion Protection Specification and chapter 17.9 of this specification whereby the Contractor shall demonstrate relevant satisfactory service experience of HV transformers, with the corrosion

[2] Satisfactory service experience defined whereby there has been no major failures requiring an unscheduled outage of the HV Transformer to occur throughout the defined five year period

protection system on offer meeting this specification, in environment with high condensation, pollution and salinity.

9) The contractor shall provide reliability/ MTBF statistics for their transformers, manufactured in the same plat as tender offer, per CIGRE TB642 Transformer Reliability Survey WG A2.37

7 Network Parameters

The equipment shall be suitable for installation on the Irish Transmission system. Refer to XDS-GFS-00-001 for further details.

Refer to project documentation including the project protection specification and single line diagram for details of relevant primary currents and voltages.

Refer to clause 17.2.3 for information in relation to earthing of transformer neutrals.

8 Environmental Design and Hazardous Substances

The Customer shall comply with all current applicable Irish and European environmental legislation. Refer also to clause 4 and the Health and Safety section of XDS-GFS-00-001.

This includes compliance in relation to:

- Declaration of materials
- Declaration of Hazardous Substances
- Safety Data Sheets and Packing Waste
- Disposal of Material Found to be Hazardous

EIRGRID reserves the right to adapt (with agreement) these requirements during the course of a contract in the event of a change of law in either Ireland or the European Union governing such matters.

The Customer shall identify in the Technical Schedules any features of the offered equipment which would contribute to EIRGRID's policy of becoming as sustainable as possible.

Careful material selection, processing and design shall be required to avoid corrosion related problems. A marine/coastal Environmental Protection Design which does not require maintenance for the first 20 years shall be required and shall be applicable to all accessories including protective devices.

Corrosion protection of all metal fittings shall be designed to achieve a Very High Durability (above 20 years) coating to Category C5-VH (ISO 12944-2 2018) suited to environments with high condensation, pollution and salinity.

In addition, the Customer shall include a priced option for any additional features which would contribute further to this policy.

9 Quality Assurance

9.1 General

General quality assurance requirements for all projects are outlined in XDS-GFS-00-001.

A formal design review will be carried out by EIRGRID at the manufacturer's works at a suitable point in the design process in accordance with the methodology detailed in CIGRE brochure 529.

An inspection of the tank manufacturer's works will also be carried out in conjunction with the design review or as a witnessed control point during the manufacture stage unless EIRGRID has recently inspected these works.

9.2 Material Workmanship

All materials and workmanship shall be of a suitable type and quality to ensure that the equipment will operate satisfactorily in accordance with the specification.

An example of each external device e.g. thermostat, Buchholz relay, etc which the manufacturer proposes to use on the transformer shall be made available during the design review for the EIRGRID's inspection and assessment (in particular in relation to design against ingress of moisture and suitability for marine environment – offshore category).

9.3 Quality Assurance System

The Customer and equipment Manufacturers shall have ISO 9001 registration and maintain a documented quality control and quality assurance system which shall be in accordance with ISO 9001 or an equivalent international standard"

Details of particular quality requirements must also be observed, including but not limited to:

- Maintenance of a risk register.
- Recording of non-conformances and follow-up corrective action.
- Evidence of continuous improvement and reviewing of targets and objectives.
- Procedures and work instructions to facilitate quality production.
- Statistical records of Quality Control Tests:

Sample copies of completed statistical records on tests and quality control checks within the factory should be provided, in order to provide confirmation of Quality Control Procedures.

Details of the inspection tests and procedures for incoming raw material should be provided. Where the Supplier relies on Quality Control testing being performed by the Supplier, details shall be provided of the tests carried out by the Supplier and the confirmatory control tests by the Customer. Copies of the actual record sheets being used are required.

- Auditing:

  In the event of quality problems which are likely to cause an impact on EIRGRID equipment being supplied, the Supplier must inform EIRGRID immediately. In the case of faulty equipment being returned by EIRGRID, the Supplier must provide a preliminary report within two weeks of receipt of the goods, and a final comprehensive report within a further 4 weeks.

  The Customer also undertakes that in the event of any contract award, the Customer will notify EIRGRID immediately of any quality issues or defects which may subsequently come to light either with this particular equipment or with similar equipment with other customers.

  EIRGRID reserves the right to conduct an audit to ensure compliance.

- Changes in Product details:

  As per the initial submission documentation, the supplier undertakes that the product(s) will be manufactured as specified and agreed and that there will be no change to the product or manufacturing process during the life of the contract without prior written approval from EIRGRID. In addition, the supplier undertakes to notify EIRGRID in advance of any proposed changes to the installation/maintenance procedures of the product(s) on this contract.

9.4 Sub-Suppliers

The Supplier shall fully declare all sub-suppliers of material associated with or used in the final product. This declaration shall include Sub-Suppliers' names and countries of origin.

It is desired that all sub-suppliers will have an implemented Quality Assurance system conforming to ISO 9001 ~ 2000 or similar standard.

Suppliers shall not alter the declared sub-suppliers without prior approval of EIRGRID. All sub-supplier information must be provided in accordance with the Technical Schedules.

9.5 Product Quality Assessment

If requested during the Customer evaluation process, the Customer shall make available in the factory, or other convenient location, a fully assembled example of each of the items offered for inspection by EIRGRID.

This inspection will cover two areas:

1. Witnessing by EIRGRID of the full assembly and adjustment process to evaluate the level of skill and experience required to complete the process successfully.

   The equipment shall first be adjusted with no physical loads applied to the HV terminals. Once the set-up is complete the rated cantilever loads shall be applied and the equipment readjusted.

   EIRGRID will also review the level of the tolerances available during the adjustment and the overall clarity of the installation manual.

2. A detailed inspection of the equipment by EIRGRID to evaluate the quality of the design and manufacture in relation to corrosion resistance, elimination or control of possible failure mechanisms and ease of operation.

10 Delivery

Packaging, delivery and storage shall be in accordance with best practice and Manufacturer's recommendations.

Refer also to delivery requirements of XDS-GFS-00-001 and any particular requirements made in project specific documentation.

10.1 Packing, Labelling and Storage

Transformer equipment shall generally be shipped directly by dedicated transport to the foundation in the station in which it is to be installed.

Where the equipment is to be accepted on site by the ESB (Asset Owner), all items shall be clearly labelled with item identification number and gross weight. Item identification numbers shall be clearly referenced on the delivery/packing note.

Items of equipment being transported by routine forwarding methods shall conform to delivery requirements of XDS-GFS-00-001.

Items requiring particular care (e.g. Bushings) shall be clearly identified and provided with appropriate packing suitable for long term storage.

10.2 Transport

The transport dimensions shall be advised to the EIRGRID at least 6 weeks in advance and will specify a required maximum height if such restriction is imposed by access roads.

As specified in section 16.13.3 Routine Tests, a Frequency Response Analysis of the windings shall be carried out following completion of tests and before shipping.

The Customer shall be responsible for the adequacy of the transport arrangements in so far as they may have a bearing on the behaviour of the transformer in subsequent service.

Transport accessories such as jacking pads, blanking-off plates, air bottles etc., shall become the property of the ESB (Asset Owner) after delivery of the transformer.

Transportation requirements shall be detailed in the functional specification XDS-GFS-00-001.

11 Site Installation and Commissioning

11.1 Installation

Installation instructions shall be provided by the Supplier in accordance with XDS-GFS-00-001 "110/220/400kV Substation General Requirements".

The instructions shall be clear, specific to the equipment being supplied and in English. These instructions shall cover all aspects of installation up to and including putting into service.

The Customer shall be responsible for the manufacture, delivery and offload to the foundation of the transformer at site in Republic of Ireland. The Customer shall provide assembly supervision services for the assembly and oil filling of the transformer.

11.2 Installation Support

The Supplier may be required to provide suitably qualified persons for on-site corrections/ modifications/ installation.

These staff shall be subject to all Health & Safety requirements. See clause 3 for further information.

At a minimum, the assembly supervisor shall carry out the following (non- exhaustive list) works as part of the assembly;

1. Confirm delivery and offloading has been performed without damage to the transformer
2. Supervise and direct the assembly of the transformer in accordance with the manufacturer's instructions
3. Perform functional checks and verification of the mechanical and protective devices after assembly including the gas in oil monitor and conditional monitoring system
4. Verification and function of all mechanical position indication devices such as OTI's, WTI's and OLI's Verification and function of all auxiliary circuit of the local control cabinet including cooling fans and pumps
5. Confirmation of installation of the rating plate and its information as per approved documentation
6. Inspection, touch-up and repairs of the corrosion protection system of the complete transformer including repair of scuffs or scratches occurring during the offload and assembly.
7. Perform a tank overpressure test to verify the integrity of all oil seals and valves. The Customer shall supply sufficient dry air bottles with the transformer in order to perform this verification test.
8. Supervise the oil filling process. The Customer shall advise the minimum times required for the oil filtration and maximum moisture levels or content allowable in the 'Fit for Service' declaration.
9. Works on site shall be carried out in accordance with Irish health and safety regulations. See clause 3 for further information.
10. Upon completion of the assembly and testing, the Customer shall provide the EIRGRID with;
11. Declaration that plant is 'Fit for Service' signed by an authorised Engineer or Agent of the Customer,
12. Full set of documentation including factory and on-site test and results.

11.3 Site Commissioning

The Customer shall schedule appropriate staff to test and commission specialist equipment such as the gas in oil monitor (DGA Monitor), conditional monitoring system and fibre option temperature monitoring devices during the assembly period.

The Customer shall perform a Frequency Response Analysis (FRA) measurement as part of site acceptance. This is to verify that no damage was done to the transformer during shipping and /or installation. The site FRA test results shall be compared to the FRA test results during Factory acceptance.

The ESB's (Asset Owner) commissioning staff may witness the Customer's test and commissioning process and request copies of inspection schedules and test reports for inclusion in the equipment commissioning file. The ESB's Commissioning staff may also independently repeat some of the commissioning tests.

12 Maintenance

12.1 General

The Manufacturer shall provide with the tender the recommended maintenance interval of their design and highlight the advantages of the design with respect to maintenance.

Refer to EIRGRID Asset Maintenance Policy document TAM-AMP-2008-I01 and the functional specification XDS-GFS-00-001.

12.2 Special Tools

The Customer shall list any special tools required for maintenance of the equipment in the schedule of Special Tools (part of Technical Schedules). All such tools shall be provided with clear instruction in English as to their function and operation.

12.3 Spare Parts

Refer to general spare parts requirements in EIRGRID functional specification XDS-GFS-00-001 '110/220/400 kV Substation General Requirements'.

The Customer shall guarantee the continuing availability of the complete range of spare parts for the lifetime of the equipment offered.

The Customer shall list spare parts which the Manufacturer recommends should be held by the TAO in the schedule of Recommended Spares (part of Technical Schedules).

All recommended spare parts, types and quantities plus any additional requirements of the TAO shall be agreed with the TAO.

All spare parts shall be provided with a description of their function, complete installation instructions and associated drawings. All instructions shall be in English.

Spare parts shall be delivered suitably packed and treated for long periods in storage.

Each packing shall be clearly and indelibly marked with its contents, including a designation number corresponding to the spare parts list in the maintenance instruction.

12.4 Maintenance Instructions

The Customer shall provide a complete set of maintenance instructions. The instructions shall be complete, in English and contain all associated instructions and drawings pertaining to the continuing maintenance of the equipment throughout its lifecycle.

13 Warranty

The equipment, including the main components of the transformer (i.e. windings, OLTC, bushings and all HV components such as leads, solid insulation and HV connections within the tank), and accessories (secondary cabling, terminal boxes, mechanism boxes and principle devices such as OLI's, FOs, WTI's, OTI's, PRDs, Buchholz), shall be fully guaranteed against all defects arising from faults in design, manufacture, assembly at site, and workmanship for a five (5) year period post-handover of the Substation.

All secondary cabling/wiring, terminal boxes, mechanism boxes and principle devices such as OLI's, WTI's, OTI's, PRDs, Buchholz shall have been tested and verified by the Customer assembly staff before declaration of completion and fitness for service has been signed.

However, the warranty period a five year shall apply to the corrosion protection system and all accessories for protection against moisture ingress.

The Supplier shall choose accessories that offer a suitable level of moisture ingress protection (min IP65), corrosion resistance and durability (above 20 years - lifetime in an atmosphere of category C5-VH according to ISO 12944-2: 2017, i.e. environments with high condensation, pollution and salinity) to meet this requirement.

Should any defect occur during the above period, the Customer shall deliver all components necessary to correct the fault, together with any necessary instructions and specialist assistance free of charge. All defects notified within the above warranty periods shall be rectified entirely at the Manufacturer's expense.

Refer also to XDS-GFS-00-001 '110/220/400 kV Substation General Requirements'.

14 Compliance with Specifications

14.1 Deviations from Specification

The Customer shall list all deviations from the requirements of this Specification in the schedule of deviations within the Technical Schedules.

EIRGRID reserves the right to reject proposals which do not comply with this specification.

Where deviations are proposed in the design the Customer shall also submit a formal Derogation Request outlining an explanation of why the non-compliance is expected and any additional information to support the request for EIRGRID to consider. Further information is outlined in EIRGRID's Derogation Process Guidance document XDS-GGD-00-001.

14.2 Conformity of Works with this Specification

Where the Customer proposes a deviation from the detailed requirements of the Specification in Technical Declaration (TD),, he shall make a written application for approval of such deviation to EIRGRID and he shall list each deviation in the Schedule of Deviations and highlight the proposed deviation on the relevant drawings. Except in the case of a deviation specifically approved in writing by EIRGRID the successful Customer shall be responsible for ensuring the conformity of the Works with the Specification, notwithstanding any general approval or lack of approval of design submissions by EIRGRID.

The low voltage control circuits shall be designed by the Customer in accordance with instructions of the EIRGRID. Once this design is approved by the EIRGRID, the Customer shall not be allowed to deviate from this approved design for this or any subsequent orders, unless agreed in writing by the EIRGRID.

15 Documentation

All documentation shall be in English. The clauses in this section outline the time by which certain types of documentation is required.

Please refer to the appropriate clauses of this specification for further requirements relating to each of these types of documentation. The Customer may submit information earlier than requested if available.

15.1 Initial Submission

General Requirements for initial project submissions are described in "Documentation to be Submitted Upon Project Initiation" in XDS-GFS-00-001.

15.2 To be Submitted with Tender

The following information is required To be Submitted with Tender:

1. Reference list demonstrating compliance with Clause 5 (1), (2a), (2b), (3) and (4) of this specification incl. transformer type and rating, production factory, year of installation and installed location.
2. Reference list demonstrating compliance with Clause 5 (5) i.e. service experience of HV & EHV transformers, with the corrosion protection system on offer, in environments with high condensation, pollution and salinity – detailing transformer rating, production factory, year of installation and installed location.
3. Reliability/ MTBF statistics, in compliance with Clause 5 (6) of this specification, for Customer's transformers over the past 10 years per CIGRE TB642 Transformer Reliability Survey WG A2.37. The Customer shall also provide details of the exact nature of the major failures.
4. Evidence of short circuit withstand test result of a similar design (as defined by IEC60076-5 Annex B) undergone in the last 5 years to demonstrate short circuit withstand capability – Clause 16.2.5 refers.
5. Graphs of short-time and long-time overload conditions indicating pre-load conditions, ambient temperature, rise in top oil temperature with time and rise in hot spot temperature with time to final loading allowed (MVA / amps). The graphs shall be provided for input and output loadings ONAN/ONAF/ODAF or OFAF only at 100% loading and long-time and short-time overloading conditions using a power factor of 0.95.
6. Loss of life curves for normal permissible duties. These curves shall show of loss of life as a function of the range K2 (Duty) = 0.8 to 2 and K1 (Life) = 0 to 1.2 as illustrated in IEC 60076-7: 2017 Annex K.
7. Full technical particulars, detailed electrical connection diagram including internal wiring, detailed physical drawings, technical literature, photographs, catalogues, technical pamphlets, reference lists, recommended spare parts, description of core earthing, etc. to enable full assessment of the offer
8. Description of the preparation and stacking of laminates.
9. General description of bushings, tap-changer mechanism box, dial thermometers, Buchholz relay, breathers, etc.
10. Winding disposition for the transformer.
11. Over-excitation curve.
12. Magnetisation curve
13. Details of winding insulation paper.
14. Details of types of core steel, thickness of steel.

15. Detailed specification of the transformer oil.
16. Outline dimensioned drawings of complete equipment.
17. Outline dimensions and weights of transport modules of plant.

In addition the Customer shall provide:

1. Any information which is required under clause 14.1 which has not already been provided for the equipment being offered.
2. Any information required in the "Before Major Equipment Orders" section of XDS-GFS-00-001.
3. A fully completed copy of the Technical Declaration/Schedules (in original file format and pdf), listing all deviations, service experience etc., etc. from this specification.
4. Supporting documentation including the items listed in Appendix 14 of the Technical Schedules.
5. Transport method statement.
6. Time required for transport from works to port of disembarkation.

Transformer Plant offered without the complete submission of the above requirements may be rejected..

15.3 To be Submitted after Order

A detailed manufacturing programme, covering all the equipment, shall be submitted within six weeks of the date of order. Thereafter, reports of progress against this programme shall be submitted at 2-monthly intervals up to including the day of despatch of the completed order.

EIRGRID shall be advised of any divergence from the submitted programme immediately on occurrence.

Complete final drawings of the equipment to be supplied, physical dimensions including all details necessary for the design of foundations, supports and support fixings, high voltage connections, equipment layout, details of secondary terminal arrangements and provision for control cables, shall be submitted for approval within six weeks of the date of order.

15.3.1 Design Documents

Design documents shall be forwarded by the Customer for approval by the EIRGRID in accordance with the following schedule:

Within three months of the Award of Contract:

a) Drawing showing physical layout in pdf and CAD formats, including high voltage connections, low voltage cable access, equipment layout, detail dimensions, volumes of oil, weights etc, for use in design of foundation and cable ducting arrangement,
b) Cable box design details, where applicable,
c) Description of the principal materials proposed for manufacturing the transformers e.g. core, windings, insulation and oil
d) A general description of the overall design method used with particular reference to core design, winding design, material clamping arrangements, dielectric design, load loss calculation, electromagnetic analysis, thermal design, hot-spot calculation, short circuit design, shielding, noise reduction measures and test considerations. The emphasis shall be on the methods used, factors considered, and techniques employed
e) Detailed physical dimensioned drawings of the transport unit.
f) Datasheets describing the on-load tap-changer (OLTC), bushings and auxiliary equipment such as Buchholz relays, dial thermometers, thermostats, fans and all other auxiliary equipment.
g) Short circuit design calculations to prove short circuit thermal withstand capability. Note that a copy of the design calculations shall be included as part of the O&M manuals for each and every transformer.

Within 5 months of the Award of Contract:

a) A complete set of physical drawings for the transformer, including transport drawings if required, OLTC and auxiliaries including details of bushings, tap-changer mechanism box, local marshalling cabinet and all other ancillary items.
b) Electrical schematics of the tap-changer control and temperature control circuits.
c) Wiring drawings of the tap-changer mechanism box and local marshalling cabinet.
d) Detailed schedule, listing all temperature protection/alarm devices and fan control devices.
e) Electrical model of the transformer for use in power system transient modelling software (EMTP etc.)
f) Contents list for record folders.
g) Detailed Schedule of Tests.

Following approval of the drawings, the Customer shall furnish a complete set of drawings on disc in one of the following formats:

i. Microstation.dgn
ii. Acad.dwg
iii. Misc.dxf 3D files of type: .stp .sat .ifc

15.3.2 Safety File

The design shall ensure safety of personnel during the installation, operation, time-based inspection, periodic time-based maintenance schedule of the EIRGRID and eventual decommissioning, dismantlement, removal.

The design shall;

a) ensure the safety of personnel during operation and restriction of material damage in the event of an internal or external fault
b) ensure safe maintenance operations, such as inspection of the sheds and cleaning; can be performed while maintaining the safety of personnel to the highest level.

15.4 To be Submitted prior to Delivery

See also XDS-GFS-00-001 “Before the Delivery of Equipment”.

Four weeks prior to the delivery of the equipment 3 copies of the technical record folder shall be supplied in hardcopy and electronic format for each type and voltage rating.

This folder shall include:

a) Completed Finalised Technical Schedules (in original file format and pdf) with guaranteed rated values and characteristics
b) Final fully detailed drawings of the equipment to be supplied including physical dimensions including all details necessary for the design of foundations, support fixings, high voltage connections, equipment layout, details of secondary terminal arrangements and provision for control cables.
c) Detailed storage, installation, operation and maintenance instructions.
d) Required environmental certification.
e) The manufacturers recommended oil testing procedure
f) The manufacturers recommended the first oil filling procedure
g) Final Test report comprising:
    - Summary sheet with list of all tests

- Detailed results and measurements for all tests performed - including routine testing, factory acceptance testing, type tests and special tests.
- Calibration certificates for all test equipment used
- Quality documentation for the equipment – including incoming quality checks etc.
- Type and special test certificates
- Serial numbers of tested equipment

16 Training

The Customer shall include a proposal for the TAO's technical staff on the proposed equipment. This shall include prices for training at both the Manufacturer's works and in-house training on EIRGRID's premises. The training shall include courses on the erection, commissioning, operation and maintenance of the equipment.

For details see functional specification XDS-GFS-00-001 section 8.9 "Training", especially subsections 8.9.1 and 8.9.2.

17 Type and Duty

17.1 General

The transformers covered by this specification will be installed outdoors in 400 kV, 220 kV and 110 kV transmission substations for interconnection of networks at these voltages.

The transformers covered by this specification include:

- 400/ 220 kV autotransformers and double wound transformers
- 275/ 220 kV autotransformers
- 220/110 kV autotransformers and double wound transformers
- 400/110 kV double wound transformers

For 400/ 220 kV and 220/ 110 kV transformers the project technical schedule will advise whether an auto transformer or double wound transformer is required.

Each transformer shall be three phase 50 Hz with Oil Natural Air Natural (ONAN) cooling supplemented as required by Oil Natural Air Forced (ONAF), Oil Forced Air Forced (OFAF), or Oil Directed Air Forced (ODAF) cooling.

All transformers shall have a delta stabilising tertiary winding.

All transformers shall have an on-load tap-changer mounted in the star point of the high voltage winding of the double wound transformer.

The transformers shall be used to control the flow of active and reactive power from either high voltage (HV) to lower voltage (LV) side or LV to HV side. Power flow in the reverse direction shall not be limited.

The neutral terminals shall be directly connected to earth or otherwise treated as indicated in clause 17.2.3.

17.2 Ratings

The rated power of the 400/220, 220/110 and 400/110 kV transformers shall be

17.2.1 Power Ratings

Table 5 Typical Nominal Transformer Ratings

Voltage	Power Ratings	Comment
400/ 220kV	500 MVA	Shall be available on all taps on the low voltage winding at a frequency of 50 Hz
220/ 110 kV	250 MVA or 125 MVA	
275/220 kV	600 MVA	
400/ 110kV	500 MVA	

The required MVA will be confirmed in project specific documentation.

The transformers shall be designed to operate with ambient temperature at the installation site in line with clause 5.1 of IEC 60076-2 and clause 4.2 of IEC 60076-1, i.e.;

- 40°C at any time
- 30°C monthly average of the hottest month
- 20°C yearly average

Each transformer shall be capable of supplying its rated power continuously under maximum ambient temperature of 20°C conditions, without the temperature of the top oil exceeding 80°C (temperature rise of the top oil ≤60°K), and without the average temperature of the windings exceeding 85°C (average temperature rise of the windings ≤65°K) during oil natural or oil forced cooling and without hotspot temperature exceeding 98°C (temperature rise of hotspot of the windings ≤78°K).

The winding hot spot temperature shall not exceed 98°C under 100% rated continuous power at 20°C ambient (yearly average).of supplying at a minimum 60% of its rated power with ONAN cooling. The winding hot spot temperature under continuous 100% rated load conditions shall not result in:

i. excessive ageing of insulating paper and
ii. reduction of normal life expectancy of transformer of over 40 years.

Note: per IEC 60076-2, a 20 °C average annual ambient temperature is generally described with permissible temperature rise in °K unless otherwise stated. The Contractor shall ensure the above operational temperatures are adhered to including in the event of a sound enclosure installation and limited air circulation.

Transformers shall also carry:

i. A long-time emergency loading of 130 % rated power for minimum of 2 hours in accordance with IEC 60076-7, as described in 16.2.11 at a preloading condition of 75 % of rated power prior to the long-time emergency loading.
    a. Calculation and measurement of temperature rise vs time to reach maximum permissible winding hot spot and inner core hot spot temperature limit of 140 °C against average ambient temperature of 20°C for long-time overload of 130% per IEC 60076-7 and time specified above (2 hours). It shall be assumed that the transformer has been continuously loaded to 75% of nameplate rating prior to the long-time overload.
ii. A short-time emergency loading of 150 % rated power for minimum 30 minutes in accordance with IEC 60076-7 with a preloading condition of 90 % rated power prior to short-time emergency loading.
    a. Calculation and measurement of temperature vs time to reach maximum permissible winding hot spot and inner core hot spot temperature limit of 160 °C against average ambient temperature of 20°C for short-time overload of 150% per IEC 60076-7 and time as specified above (30 mins). It shall be assumed that the transformer has been continuously loaded to 90% of nameplate rating prior to the short time overload.

The tertiary stabilising winding shall be designed for 33 % of rated power and shall be subject to the same overload conditions as the primary and secondary windings and fault withstand level as specified in clause 16.2.5. The tertiary terminal arrangement shall be according to clause 16.8.1. Its function is for stabilisation, and it shall be connected to earth during service.

Table 6 Rated Power under different loading and cooling conditions (MVA)

	400 kV/ 220kV 500 MVA		400 kV/ 110kV 500 MVA		275 kV/ 110kV 250 MVA		220 kV/ 110kV 250 MVA		220 kV/ 110kV 125 MVA	
	With Cooling	ONAN	With Cooling	ONAN	With Cooling	ONAN	With Cooling	ONAN	With Cooling	ONAN
HV and LV Windings 100 % rated power continuous Loading [3]	500	300	500	300	600	400	250	150	125	75
Tertiary Winding	167	100	167	100	TBC	TBC	84	50.4	42	25.2
Tertiary Winding 130 % rated power 2 hour emergency overload	217	130	217	130	TBC	TBC	109	65.4	55	33
HV and LV Windings 150 % rated power 30 minute emergency overload	750	450	750	450	900	600	375	225	188	112.8

The Customer will be required to demonstrate the overloading capability by temperature rise tests, see clause 17.14.2 (a).

The Contractor shall advise the calculated hot spot temperature.

Thermally upgraded paper shall be used for winding insulation.

The Customer shall supply loss of life curves for normal permissible duties. These curves shall show details in the range K2 (Duty) = 0.8 to 2 and K2 (Life) = 0 to 1.2

Bushings, tap-changer, leads and other current-carrying parts shall be rated to carry the emergency above overloads capability up to 130 % rated power for a minimum of 2 hours and overload capability up to 150 % rated power for a minimum of 30 minutes. The actual over loading capability of these components shall be stated in the Technical Schedules.

The overloading capabilities (long- and short-time) shall be provided by the Customer and shall be proven by both calculation and type test incorporating direct temperature measurement of the hotspot, see clause (b) of 16.13.2. The calculated graph of the heat rise shall show with each overloading case the pre-load condition and the rise in temperature with time to the final loading allowed. A comparison of the calculated loading condition (shown in Amps) against the type test measurements shall be provided. Direct winding temperature measurement (via fibre optic probes) method shall be used in all cases and considered as final in event of any conflict between calculated and actual measured results.

[3] Both primary and secondary windings shall be rated for total transformer MVA to allow full power flow in either direction.

For normal and overloading conditions, the harmonic content of the load voltage shall be considered up to the maximum level of 5 % Total Harmonic Content as per IEC 60076-1 with even harmonic content of 1 %. Load current harmonic content up to a maximum level of 5 % of rated current shall be allowed for.

The magnetisation curve and type of core steel for the transformer shall also be provided by the Customer. Minimum requirements related to type of steel, thickness and specific loss [W/kp] are as follows:

Table 7 Steel Requirements

Type of steel	Laser etched silicon steel or Cold-rolled non-aging silicon steel
Thickness	0.23 mm or better
Specific Loss at 1.5 T [W/kp]	0.53 or better

The tap changing equipment shall not be a limiting factor for overload rating of the transformer.

Transformers of the same voltage ratio and equal power rating shall be capable of being paralleled with one another by the in-step method.

17.2.2 Voltage Ratios

The tap-changer shall be connected to the higher voltage winding (or in the case of auto-wound transformers, the series winding).

All tappings shall be rated for maximum system voltage and full power.

17.2.2.1 400 kV Transformers

The no-load ratios shall be as required by the technical schedules. The tap-changer is connected to the higher voltage winding and the voltage on each tap is given for constant voltage on the lower voltage winding. Typical specifications are shown in Table 7. The principal tap is tap 12.

Table 8 No-load ratios for 400 kV Transformer

Tap Position	Voltage across HV windings (kV $_{L\text{-}L}$)	Rated voltage across LV Windings (kV $_{L\text{-}L}$)
1	420.0	For the 400/220 kV transformers LV is 220 kV For the 400/110 kV transformers LV is 110 kV
2	415.6	
3	411.3	
4	406.9	
5	402.5	
6	398.1	
7	393.8	
8	389.4	
9	385	
10	380.6	
11	376.3	
12	371.9	
13	367.5	
14	363.1	
15	358.8	
16	354.4	
17	350	

17.2.2.2 220 kV Transformers

The no-load ratios shall be as required by the technical schedules. The tap-changer is connected to the higher voltage winding and the voltage on each tap is given for constant voltage on the lower voltage winding. Table 9.

The principal tap is Tap 5.

Table 9 No-load ratios for 220 kV Transformers

Tap Position	Voltage across HV windings (kV_{L-L})[4]	Voltage across LV windings (kV_{L-L})
1	241.4	..
2	237.3	..
3	23.2	..
4	229.1	..
5	*225	..
6	220.9	..
7	216.8	..
8	212.7	..
9	208.6	With 110 kV across LV windings
10	204.5	..
11	200.4	..
12	196.3	..
13	192.2	..
14	188.1	..
15	184	..
16	179.9	..
17	**175.85	..
18	**171.75	

275 kV Transformers

[4] Where indicated in project specific requirements the Customer shall quote for the option of a 21 % impedance transformer with 18 Taps.

Table 10 No-load ratios for 275 kV transformers

Tap Position	Rated voltage across HV Windings (kV $_{L-L}$)	Voltage across LV windings (kV $_{L-L}$)
1	For 275/220 kV transformers the HV voltage is 275 kV	254.6
2		251.6
3		248.5
4		245.4
5		242.4
6		239.3
7		236.2
8		233.1
9		230.1
10		227.0
11		223.9
12		220.9
13		217.8
14		214.7
15		211.7
16		208.6
17		205.5
18		202.4
19		199.4
20		196.3
21		193.2
22		190.2
23		187.1

17.2.3 Rated Insulation Levels

Table 11 Rated Insulation Levels (kV)

Item	Voltage (kV)	Voltage (kV)	Voltage (kV)	Voltage (kV)	Voltage (kV)
Nominal Voltage	400	220	300	110	10.5[6]
Rated Voltage	420	245	300	123	12
Terminal Insulation Levels					
Full Wave Lightning Impulse (peak)	1550	1050	1050	550	95
Chopped Wave Lighting Impulse (Peak)	1,705	1,115	850	605	-
Switching Impulse (peak)	1175	850	460	460	--
Power frequency withstand	630	460	460	230	28
Neutral Insulation levels					
Lightning Impulse	550	550	550	550	
Power frequency withstand (separate source)	230	230	230	230	-

The Tenderer shall ensure that the insulation of all windings and connection leads is adequately designed for system insulation levels in accordance with IEC 62271-1 and IEC 60076-3.

Transformer neutrals will be operated as indicated in

Table 12 Treatment of Neutrals

Transformer Voltages	Autotransformer Neutral	Double Wound	
		HV Neutral	LV Neutral
400/220	Effectively earthed	Effectively earthed	Effectively earthed
400/110	N/A	Effectively earthed	Effectively earthed
275/220	Effectively Earthed	Effectively Earthed	Effectively Earthed
220/110	Effectively Earthed[7]	Effectively earthed	May be Effectively earthed, isolated or impedance earthed[8]

The standard wave shape shall be obtainable on any of the terminals. The Tenderer shall state in the tender if the standard IEC impulse test wave shape is not obtainable on any of the terminals and shall specify the wave shape to be expected in such cases.

[6] Tertiary Winding Parameters: The figures quoted refer to a nominal tertiary voltage of 10.5 kV. The insulation level of the tertiary stabilising winding shall be agreed between EIRGRID and the successful Tenderer.
[7] Unless otherwise indicated in project documentation.
[8] Note: Impedance earthing may be achieved with either a Neutral Earth Resistor (NER – typically 5-7 ohms) or a Neutral Earth Reactor (NEX).

The use of Metal Oxide Surge Arresters (MOSA's) and similar types of overvoltage protection devices (e.g. MOVs) in the design of the transformer shall not be acceptable to EirGrid for the following reasons:

1. The use of these devices adds an extra component whose failure would reduce the reliability of the transformer.
2. If these devices fail on open circuit, it will not be detected. The designed function of the device is no longer in place, and the transformer will not be protected from over-voltages.
3. If these devices fail by short circuit, the transformer fails. Insulation to ground may be compromised by either of the following:
    a. The device insulation may deteriorate.
    b. Deteriorating transformer oil may affect the insulation of the device to ground.

Auxiliary Circuit insulation levels will be as follows:

Dielectric withstand r.m.s. - 2 kV, 50 Hz, 60 s

17.2.4 Winding Connections and Vector Groups

The Primary/Secondary/Tertiary connection of all transformers shall be Star/Star/Delta.

The vector group shall be YNyn0d5 for double wound transformers.

The vector group shall be YNa0d5 for autotransformers.

17.2.5 Short Circuit Withstand

The transformer shall be rated for the following network parameters:

Table 13 Network Parameters

Parameters	Networks - Nominal Voltages				
	400 kV	220 kV	275 kV	110 kV	10.5 kV
Rated Voltage	420 kV	245 kV	275	123 kV	12 kV
3 Phase Short Circuit Current rms)t	50 kA	50 kA	50 kA	40 kA	20 kA9
Duration of Short Circuit	1 s	1 s	1 S	1 s	1 s
Dynamic Current (peak)	125 kA	125 kA	125 kA	106 kA	50 kA

X/R ratios of the 110 kV network may be as high as 25 resulting in dynamic peak of 126 kA for single phase to earth faults. The Customer shall ensure the tertiary winding is suitably designed to withstand single phase to earth faults which can arise higher fault currents on the 110 kV system then phase to phase faults as shown.

Transformers, including all equipment and accessories shall be capable of withstanding without damage the thermal and dynamic effects of short circuits of all types on either the HV or LV winding with rated voltage on the other winding and the tap changer in any position as specified in IEC 600760-5, and with the following parameters:

- Thermal Ability – duration of current: 2.0s
- Dynamic Ability - duration of current: 0.5 s

[9] Note: the nominal short circuit rating for MV network equipment is 20 kA and for information purposes only. The transformer manufacturer shall ensure the tertiary winding of the transformer is sufficiently rated to withstand the fault current that may flow in the tertiary winding during a single phase to earth fault on the HV or LV side of the transformer.

- Dynamic Ability - number of tests: 9
- Symmetrical three phase system short circuit currents and corresponding peak short circuit currents are defined in XDS-GFS-00-001. Increased short system circuit currents and X/R ratios may apply in some cases. [10] Refer to project specific requirements including the protection specification and SLD.

The Customer shall submit evidence of at least one short circuit withstand test result of transformers or similar transformer design (as defined by IEC60076-5 Annex B) which have undergone this test in the last 5 years to prove the short circuit performance of a similar design.

Consideration shall also be given to:

- The dynamic short circuit withstand test result of transformers in the voltage range as specified or higher inside the 5-year period from date of tender issue,

Or as an alternative the following may be considered in conjunction with clause 5(2) Service Experience;

- The dynamic short circuit withstand test result of transformers in the voltage range as specified or higher outside the 5-year period from date of tender issue, (See also Type Tests, clause 16.13.2 Test (e); Short Circuit Withstand)

The Customer shall provide calculations to demonstrate the thermal ability as part of the O&M manual for each and every transformer and design rating applicable to each winding stamped on the rating plate.

In calculating short circuit currents, the apparent short circuit power of the network and hence the network impedance used shall be deduced from the highest network voltage and rated short time withstand current.

K (asymmetry factor) is to be taken as 2.74 for purposes of proving by calculation the thermal short circuit withstand capability.

17.2.6 Impedance Voltage

The percentage impedance voltages, referred to 75°C, on principal and extreme taps shall be as specified in the Technical Schedules for the project specification.

Percentage impedances quoted refer to primary to secondary windings.

Typical specifications in % values over the tapping range are as follows.

Table 14 Impedance Voltages - 400 kV Transformers

Voltage Ratio	MVA	Notes	Type	Impedance		
				Lowest	Principal Tap (#12)	Highest Tap
400/ 220kV	500	17 Taps	Double Wound	< 14%	13.50%	> 13 %
400/ 220kV	500	17 Taps	Auto Transformer	> 13%	13.50%	< 14 %
400/ 110kV	500	17 Taps	Double Wound	< 21 %	18%	> 14 %

[10] On the 110 kV system: Urban areas with X/R = 25 can have peak currents of 106 kA for three phase faults and 126 kA for single phase faults.

Table 15 Impedance Voltages - 275 kV Transformers

Voltage Ratio	MVA	Type	Impedance		
			Lowest	Principal Tap (#12)	Highest Tap
275/220 kV	600	Auto Transformer	14.24	8.38	14.37
275/220 kV	300	Auto Transformer	13.35	9.02	14.40

Table 16 Impedance Voltages - 220 kV/ 110 kV Transformers

MVA	Type	Notes	Impedance		
			Lowest Tap	Principal Tap (#5)	Highest Tap
250	Auto Transformer	16 Taps	> 15.5 %	16 %	< 17.5 %
250	Double Wound	16 Taps	< 17.5 %	16 %	> 15.5%
250	* Auto Transformer	18 Taps 21 % variant	>19.62 %	21 %	< 22.8%
250	* Double Wound	18 Taps 21 % variant	< 22.8%	21 %	> 19.62 %
125	Auto Transformer	16 Taps	> 15 %	15.50 %	< 17 %
125	Double Wound	16 Taps	< 17 %	15.50 %	> 15 %

The IEC allowed deviation for impedance voltage at each tap shall apply.

The % impedance of the tertiary winding, if not specified, shall generally be in accordance with the requirements of EN(IEC) 60076-5.

*Where indicated in the Enquiry, the Customer shall quote for the option of a 21 % Impedance dual wound & auto-transformer with 18 Taps.

17.2.7 Zero Phase Sequence Impedances

Tenderers shall state, in the Technical Schedules, the zero phase sequence impedances of the HV and LV windings, i.e. HV winding with LV open, HV winding with LV shorted to neutral, LV winding with HV open and LV winding with HV shorted to neutral. In the case of autotransformers, the HV to LV impedance with the neutral floating shall also be given. Test to be carried out with Tertiary winding closed.

The Customer shall also state in the type test report, the value of zero sequence impedance as a percentage of the positive sequence impedance. A measurement of zero sequence impedance shall be performed on the first transformer of every size/type supplied and in case that the design is changed and shall be included in the routine test report together with the serial number of the tested transformer as well as the date of test as a reference.

17.2.8 Over-Fluxing

The transformers may be subjected in service to long duration 50 Hz overvoltages and short duration high frequency overvoltages. They shall be designed and guaranteed for overfluxing capability of 120 % continuously.

This shall be in addition to a margin for the deviation of applied voltage/frequency to rated voltage /frequency of 5 % (EN60076-1, Clause 5.4).

The over-excitation curve for the transformer showing volts/Hz versus time shall be submitted with the tender and shall show details in the range of 100 % to 150 % Excitation and 0 to 100 minutes.

The over-excitation capability shall be confirmed as follows in transformer tests:

- Additional losses injected during temperature rise test (See clause 17.14.2 (a))

  and

- Higher exciting voltage during measurement of No-load Losses (clause 17.14.3 (k)).

The Manufacturer shall ensure that the OLTC is suitably rated for the voltage step change between taps at the lowest frequency of operation (i.e. 47.5 Hz).

The customer shall state the maximum levels of overfluxing in terms of percent of rated voltage/frequency that the transformer can withstand without damage for the periods of 10 seconds and of 1 minute[11].

EirGrid includes over-fluxing protection in the suite of transformer protection systems. The over-fluxing relay settings are based on continuous and short duration levels. The Customer shall state the maximum levels of over-fluxing in terms of percent of rated voltage/frequency that the transformer can withstand without damage for the periods of 10 s and of 1 minute.

17.2.9 Partial Discharge

Partial discharge levels for bushings alone shall not exceed 5 pC, at service Voltage.

Where required, evidence shall be submitted by the Customer showing that the transformer has passed the partial discharge test in accordance with IEC 60076-3. Partial discharge levels for the transformer as a whole, including bushings, shall not exceed 40 pC, at service voltage. While a maximum limit of 5 pC applies to bushings tested separately.

Partial discharge limit shall apply at U2 = 1.2 Um phase to phase in deviation against IEC 60076-3 which recommends U2 = 1.3 Um.Four valves of minimum size 50 mm BSP (DN 50 (minimum) or DN 80) shall be provided to allow the insertion of partial discharge sensors for triangulation of any internal discharge activity. Valves shall be routed directly into the transformer tank without right angles or 'S' bends

PD Curves and test results shall be recorded, documented and supplied to the Employer for their records and approval.

17.2.10 Auxiliary Power Supplies

The tap changer, coolers, control and protection equipment shall be operated by the following auxiliary electrical power supplies.

a) 3 phase, 4 wire, 50 Hz (¤ 2.5 %), 400/230 V (-10 % +10 %), for tap changer and cooler motors.

b) 230 V (-10 % +10 %), for general AC circuits including lighting, heating or as required for single phase loads.

c) 220 V DC (-15 % +10 %) for trip circuits.

d) 220, 110, 48 or 24 V DC (-15 % +10 %) for alarm and signalling circuits as advised in the Technical Schedules for the particular applications.

All auxiliary supply circuits shall be protected by MCBs.

Each MCB shall be provided with a normally closed auxiliary contact to indicate MCB tripped/open.

[11] This information is required for the setting of overfluxing relays, which are included in the required suite of transformer protection systems.

All contacts shall be wired to terminals within the mechanism box for connection of external DC signal supply. All signals and alarms shall be dependant only on the relevant DC source voltage, i.e. contactors or auxiliary relays providing DC signals and alarms shall not be driven by an AC source. Any wiring changes required on site to meet the above, shall not void the warranty.

17.2.11 Overloading

Refer to Clause 17.2.1 Ratings and Clause 17.14.2 Type Tests.

Any associated equipment, for example bushings, cable-end connections, tap changing devices, leads and bushings shall not be limiting factors for overload rating of the transformer. The overloading conditions shall be type tested, with the highest load loss (tap positions 16, 17 or 18) utilising direct winding temperature measurement method via fibre optic sensors embedded in the winding to ensure the hot spot does not exceed the thermal rating of the insulation and lead to loss of life for the defined overloading conditions that may occur on average once per year.

A graph of the heat rise for each overloading situation shall be provided by the Contractor indicating the pre-load condition, with the tapping with the highest load loss or tapping with the maximum current and the rise in temperature with time to the final loading allowed, with the loading condition shown in Amps.

17.2.12 Parallel Operation

Transformers shall be designed such that they can be operated in parallel with another transformer of same MVA rating, vector group, percentage impedance and turns ratio. They shall share current to within 10 %. Transformers shall be capable of being paralleled with one another by the in-step method.

17.3 On-Load Tap-Changer

17.3.1 General

The transformer shall be provided with MR Reinhausen or Hitachi VACUUM type in-tank On-Load Tap-Changer (OLTC) for 400 kV, 275 kV and 220 kV transformers which shall be designed for continuous operation at the full power and overload ratings of the transformer.

A combined selector/diverter switch type tap changer is not acceptable.

The OLTC shall be situated electrically at or near the HV neutral point and rated in accordance with the insulation levels as specified in Clause 16.2.3.

The Customer shall note that the corrosion requirements of this specification apply to the tap-changer and shall be therefore provided as an offshore type to fully comply with EIRGRID requirements.The tapping range, the number of steps and tap positions shall be in accordance with the requirements specified under Clause17.2.2.

The tap-changer shall comply with IEC 60214 – On-load tap-changers and shall be designed for the insulation level of the HV winding to which it is connected.

A “Raise” command e.g. from tap 2 to tap 3, shall signify an increase in the lower voltage with a constant voltage on the higher voltage winding.

The mechanism and controls shall be suitable for parallel operation of transformers by the in-step method.

Each transformer shall be supplied with a tap-changer mechanism box containing all control equipment associated with the on-load tap-changer.

Moving parts, including the tap changer drive shaft, which are accessible to operation and maintenance personnel, shall be provided with guards which shall provide a minimum degree of protection IP2X according to IEC 60529.

Paint and corrosion protection for the OLTC shall comply with the marine environment long term corrosion resistance specification as per clause17.16. The Manufacturer shall ensure the OLTC used is installed in

accordance with the supplier's instructions for use in marine or offshore environments. Cover bolts on the selector switch shall be suitably greased or protected from corrosion on installation at the transformer factory.

Where three single phase tap changers are provided the phase rotation shall be clearly marked externally.

Refer to section 0 for required tap changer service experience.

Design screws, washers, nuts etc. shall be in accordance with ISO 3506-1/ISO 3506-2 standard.

All OLTC leads shall be bolted – no riveting of leads shall be allowed.

17.3.2 Compartments

The tap change diverter switch shall be housed in its own oil and gas tight compartment supplied from a separate section of the conservator tank.

The tap changer compartment shall be equipped with siphon pipes, fitted with valves etc. in accordance with sub-clause 17.5.9 and be accessible from ground level.

Adequate access for personnel shall be provided for inspection and maintenance purposes.

To facilitate inspection and maintenance of the tap changer switch, it shall, where required, be possible to drain the oil in the transformer below the top of the windings.

The section of the conservator tanks utilised for the OLTC shall allow at least 8 one litre samples before top-up is required.

The mechanism box or cabinet shall be at a convenient level, arranged for ease of inspection and fitted with a heater.

17.3.3 Drive Mechanism

a) The tap-changer shall be driven by a motor-operated mechanism incorporating a stored-energy device which shall ensure that once a change of tap begins it is completed and so shall ensure that the mechanism does not fail in an intermediate position on loss of the supply voltage to the motor.

b) The motor drive control shall be such that on initiation of a tap-change operation by means of a control switch or push-button, the tap-changer shall complete its movement from one service position to an adjacent one irrespective of whether or not the control switch or push-button has been operated continuously during the running time of the motor drive. Another operation shall only be possible when the control switch or push-button has been released and the control system is again in the rest position.

c) The motor shall be operated by 400/230 V +10% -15%, 50 Hz and shall be rated for maximum ambient conditions.

d) Limit switches shall be provided to prevent over-running of the tap-change mechanism. These shall be directly connected in the motor circuit. In addition, mechanical end stops shall be fitted to prevent over-running of the mechanism under any conditions.

e) The handle or crank for manual operation shall be at a convenient level over ground and interlocked with the motor supply so that the motor cannot be energised when the handle is being operated.

f) A safety device, for example, de-clutching and/or shear point, should be incorporated in the drive between the motor and the tap change mechanism to prevent damage to the mechanism in the event of incorrect operation of the limit switches for any reason. Tenderers shall state whether the limit switches are made in the transformer Manufacturer's works or if they are obtained from Specialist Manufacturers. Details shall be included in the Technical Schedule.

17.3.4 Tap Changer Mechanism Box

A tap changer mechanism box shall be provided, for the control of the tap changer and all associated control equipment, instrumentation and wiring etc as required, including the equipment and functionality described in clause 17.3.5.

The box shall be fitted to the transformer at a convenient height and location for operators and shall be fitted with anti-vibration mountings.

The base of the box shall be a minimum of 600 mm above the base of the transformer to allow for bund walls and the maximum height of the top of the box shall be 2 m above ground level to allow viewing of all temperature dials without opening the door.

The door of the marshalling box shall incorporate a strengthened glass or polycarbonate window to allow external viewing of the tap position indicator.

The marshalling box shall meet the requirements for enclosures as stated in XDS-GFS-17-001.

17.3.5 Control and Indication

The following control and indication facilities shall be provided in the tap changer mechanism box:

a) Local push button control.

b) Facilities for manual operation of the tap changer, in event of loss of auxiliary supply.

c) An interlock which will automatically interrupt the electrical supply to the drive motor when the manual operation device is engaged.

d) An operation counter.

e) Two mechanical tap position indicators.

   One shall be visible to a person standing at ground level through a window on the front of the mechanism box.

   One shall be mounted in the diverter switch compartment and shall be visible from the top of the main tank.

f) A remote tap position transducer with options of digital display and mA signal output (both 0-10 mA and 4-20 mA, 300 Ω) shall be provided to indicate the tap position in the control room. This transducer will be wired to a terminal rack in the mechanism box. Supply of the transducer and digital display unit shall be included in the scope of supply.

g) Two stud switches wired to suitable terminals in the mechanism box for:

   - out-of- step alarm signal during parallel operation
   - tap position indication to a system control centre

   Each tap position of each stud switch shall be wired out to terminal racks in the mechanism box.

h) Local/remote switch to facilitate operation of the tap changer from the local or remote position. The switch shall not have an off position.

i) MCB electrical protection for each circuit, with “open” and “trip” signal contacts.

j) The motor control circuit shall be fitted with temperature compensated thermal overload protection with alarm and trip contacts.

17.3.6 Terminal Blocks

All interface terminals for connection of external cables shall be screw/screw type.

All terminals must be individually numbered; each block of terminals must be identified.

Each section of terminals must have end plates and end brackets and must have an identification label to identify the terminal block.

All terminals shall be in accordance with XDS-GFS-07-001. Current transformer terminals shall allow for shorting and isolation of current transformer circuits. Refer to XDS-GFS-07-001 for further details.

17.3.7 Internal Wiring

The internal wiring shall conform to EN 60227.

The units shall be delivered with all items of equipment fully wired.

All wiring shall be methodically arranged and shall follow an orderly and tidy pattern, grouped in a logical manner according to circuits involved, and shall be adequately supported and protected from mechanical damage. Wiring shall be arranged so that access to terminals or other apparatus is not impeded.

All connections to equipment and to terminals shall be tight and shall be made off with suitable crimp type terminations. Wire looms shall be neat and shall not impede access to terminals of equipment. Connections to devices must not be under strain. Where wiring is connected to moveable equipment, such as equipment on hinged panels or doors, the conductor shall be multi-strand flexible. Wiring runs shall be so arranged as to minimise pick-up of interference or spurious transients. Not more than two wires shall be connected to any one side of a terminal.

Internal wiring shall be connected to the equipment side of the terminal blocks except where looping is required on the external cable connection side of the terminal block to provide short-circuiting facilities for current transformer secondary circuits.

Detailed layouts of the proposed mechanism/fan boxes shall be provided including all terminals, location of devices, size of trunking, etc. The proposed arrangements will be subject to the detailed design approval of the EIRGRID.

It shall be possible to bridge-out i.e. short-circuit the current transformer secondary circuits at each of the relevant file terminal blocks.

All conductors shall be stranded copper. The colour of the PVC insulation for connections to earth shall be yellow and green.

All conductors shall be stranded copper.

Conductor sizes and colours shall be in accordance with XDS-GFS-07-001.

17.4 Cooling and Temperature Control

17.4.1 Radiators

Radiators for 220 kV transformers shall be mounted on the tank.

Cooling radiators for 275 kV/400 kV transformers may be arranged in either of the following two ways.

(a) Radiators shall be mounted in a free-standing bank. Isolating valves shall be provided on the transformer tank at the inlet and outlet of the cooler bank and shall be so arranged that they may be left in position during transport. Each individual radiator shall be fitted with an isolating valve. Expansion joints shall be provided at the transformer and cooling bank ends of the pipe connections between the transformer and the free-standing bank. All valves shall clearly indicate the open and closed positions. Two oil filter valves shall be fitted in accordance with the sub-clause on oil valves in the clause on tank and accessories.

A pocket to accommodate a thermocouple device, to monitor oil temperature shall be provided in the return pipeline to the transformer from the cooling bank.

Or

(b) The radiators shall be mounted on the tank but detachable from it for transport and maintenance. Shut off valves shall be provided for this purpose. These valves shall clearly indicate the open and closed positions. A pocket to accommodate a temperature measuring device shall be provided in a return connection of two radiators, one located either side of main tank.

Bonding of the radiators to the main tank shall be ensured by means of external bonding straps across flanges.

Drainage valves shall be suitably located for ease of access and maintenance.

Refer to Oil Filtration for oil valve requirements.

All radiators shall include:

- Air bleed and oil drainage valves.
- Facilities for installation of bonding straps across flanges.
- Lifting eyes.
- Mechanical bracing and connection points as required.
- Painting as specified in clause 17.16.

Where radiators are supported on the transformer a pocket to accommodate a thermocouple device shall be provided in the return connection of one radiator on each side of the main tank.

Where a free-standing cooling bank is used:

- A pocket shall be provided in the return pipeline to the transformer.
- Expansion joints shall be provided at the transformer and cooling bank ends of the connecting pipework.
- Two oil filter valves shall be fitted in accordance with the sub-clause on oil valves in the clause on tank and accessories.

17.4.2 Fans and Pumps

Forced cooling may be ONAF, OFAF, or ODAF.

Motor driven fans and/or pumps and associated equipment and systems shall be provided as required to implement the chosen forced cooling system.

Each fan or pump motor shall be operated by 400/230 V, 50 Hz and shall be continuously rated for maximum ambient conditions.

Fans shall be fixed to the transformer/radiator with anti-vibration mountings.

If OFAF cooling is provided, each pump shall be fitted with a bypass arrangement and isolating valves, so that the pump may be removed and replaced without taking the transformer out of service

Motor enclosures shall have degree of protection IP54 and fan enclosures IP2X, in accordance with IEC 60529 and the requirements of XDS-GFS-17-001.

The automatic cooling control shall be so arranged that the cooling is applied in at least two independent stages on the transformer.

The automatic cooling control system shall include an overriding manual control switch.

Coolers shall be automatically switched on when the winding temperature exceeds pre-set values and shall be switched off when the winding temperature falls below these values.

Fibre optic direct temperature sensors shall be used to measure the winding temperature and control the coolers.

Each fan and pump shall be fitted with temperature compensated thermal overload protection with alarm and trip contacts and an individual MCB with "open" and "trip" signal contacts. Each fan, pump and associated MCB shall be numbered.

Metallic fan and pump housings should be bonded to the main tank with a dedicated earth bonding strap or lead. An earth conductor in the AC supply cable to the fan is not sufficient for this purpose.

17.4.3 Transformer Marshalling Cabinet

In addition to the OLTC control cabinet, a marshalling cabinet shall be attached to the transformer. This shall include all local controls for the coolers, all temperature dial thermometers, (OTI & WTI's), oil level indicators, alarm and trip connections, 220 kV or 110 kV neutral CT secondary circuits, pressure relief device alarms, Buchholz relay trip and alarm terminals etc. It shall be mounted on the transformer using suitable anti vibration mountings. A transformer marshalling box shall be provided to house all equipment to meet the required functionality, including the functions and devices and to marshal all associated wiring.

The marshalling cabinet shall meet the requirements for enclosures as stated in XDS-GFS-17-001.

The door of the marshalling box shall incorporate a strengthened glass or polycarbonate window to allow external viewing of dial thermometers.

The base of the box shall be 600 mm above the base of the transformer to allow for bund walls and the maximum height of the top of the box shall be 2 m above ground level to allow viewing of all temperature dials without opening the door.

17.4.4 Control Equipment

Control equipment and systems (to be installed within the marshalling cabinet) shall include:

a) Two dial thermometers to indicate the temperature of the transformer top oil.

   Each thermometer shall be fitted with:

   - Sets of independently adjustable volt free contacts, one connected to give an alarm, one to trip associated circuit breakers and two spare. Multiplication of contacts by use of auxiliary relays is unacceptable.
   - A scale from at least -20 °C to +140 °C and suitable for operation in external environmental conditions as described in XDS-GFS-00-001 "110/220/400 kV Substation General Requirements".
   - A maximum temperature pointer, which shall be re-settable by hand from ground level.
   - Mechanical protection to protect the dial from accidental strike and damage.

   The use of mercury switches is not acceptable.

   The dial thermometer used shall be subject to EIRGRID approval.

   The dial shall be mounted so that it may easily be read by a person standing at ground level, through the window in the door of the control cabinet.

b) Two dial thermometers of the same manufacture and meeting the same requirements as for (a), but which indicate the winding hot spot temperature of the central phase of the HV and LV windings using a thermal image technique.

   They shall include the following additional features:

   - A test facility for the thermal image technique.
   - Sets of independently adjustable volt free contacts, one connected to give an alarm and one to trip associated circuit breakers and two spares. Multiplication of contacts by use of auxiliary relays is unacceptable.

- A maximum temperature pointer which shall be re-settable by hand from ground level.
- Mechanical protection shall be provided to protect the dials from accidental strike and damage.
- A thermal imaging Current Transformer with a minimum burden and accuracy to complement item (a) above shall also be provided. The CT circuit shall include a shorting / test link in the terminals.
- A scale to at least 0 to +160 °C.

c) A minimum of 2 fibre optic temperature sensors per HV and LV winding (i.e. 12 no. in total), , shall be provided for real-time winding temperature monitoring and automatic control of the cooling system. The Customer shall provide suitable redundancy for the fibre optic sensors (i.e. 1 sensor per phase per HV & LV windings).

- The Condition Monitoring System (CMS) installed, the fibres from these sensors shall be connected to the CMS[13]. In this case, fibre optic conversion signal conversion shall be provided by the Customer as required as part of the overall CMS.
- The condition monitoring system specified in clause 16.7 shall indicate winding temperature, provide winding temperature alarm, and trip signals and to automatically control the two-stage cooling system.
- Probes to be brought out by an approved tank wall penetrator and that all probes shall be in a designated box, with removable cover, situated between chest and head height on the tank wall – final position subject to approval by EirGrid.
- A test facility for the fibre optic temperature sensors shall be provided by means of an additional fibre optic probe for connection to test equipment.

d) Two transducers for remote indication of HV and LV winding temperatures.

These shall be to EIRGRID's approval and may be supplied as part of (b) or provided separately.

e) Facility for the manual control of the fans and pumps shall be provided in the form of a two-position switch mounted in the marshalling cabinet. The switch shall be labelled 'Fans and Pumps' and the positions on the switch shall be labelled 'auto' and 'on'.

In the 'auto' position the fans and pumps shall be automatically controlled by the winding temperature fibre optic sensors via the condition monitoring system or fibre optic signal converter. In the 'on' position all the fans and pumps shall be switched on and remain on while the switch is in the 'on' position. There shall be no 'off' position.

f) One motor MCB per fan and pump motor.

Each MCB shall be appropriately labelled and shall have a signal contact to indicate that the MCB has been opened or tripped.

g) One MCB or isolating switch for providing the tap changer with an electrical supply from the marshalling box. This device shall be appropriately labelled and shall have signal contacts to indicate that it has been opened or has tripped. If it is an MCB its current rating shall be co-ordinated with the MCB (if fitted) in the tap changer drive box.

h) Additional items as required to complete the required protection metering and control scheme of the transformer e.g. including terminals, wiring, relays, contactors, signal converters etc.

i) All thermometers shall be remote indicating type with external probes for measurement of the oil temperature. Direct mount type shall be avoided where possible due to the environmental conditions. Where temperature probes, thermostats and thermocouples are mounted on the top of the transformer tank they shall be protected by an additional cover or shield designed and fitted by

[13] The Condition Monitoring System is described in clause 17.7

the transformer Manufacturer to provide protection from rain, snow and ultraviolet sunlight radiation.

j) Remote oil level indicators (magnetic type or similar) with auxiliary contacts for alarms/signalling of low oil levels in the main tank and OLTC conservator tank.

Note that capillary tubes for remote oil level monitors and top oil thermocouples must be provided with stainless steel protection and PVC coating.

See also 16.3.6 and 16.3.7 for terminal block and internal wiring requirements.

17.5 Tanks and Accessories

17.5.1 General

The tank shall be of welded steel plate with sufficient strength and rigidity to withstand application of full vacuum and all forces acting during transport as well as in service including pressures due to fault conditions.

Its construction shall be such that air pockets do not form inside the tank. All welding shall conform with BS EN ISO 5817 to a quality level for weld imperfections of 'Stringent' level symbol 'B'. Tank construction and welds shall be NDT tested and relevant certificates shall be produced by the customer.

An inspection of the tank Manufacturer's works will also be carried out in conjunction with the design review or as a witnessed control point during the manufacture stage unless EIRGRID has recently inspected these works.

The tank cover shall be a welded cover.

The welded sealing design should allow for grinding open and re-welding of the tank cover a minimum of 3 times over the life of the transformer in a safe manner without risk of damage to the internal of the transformer or contamination of transformer oil.

Details of welded sealing design shall be provided with the tender return.

The tank cover shall also be designed to effectively shed water.

Approval of final design for use shall be specified by EIRGRID on placement of order. The design shall be such that it does not present a hazard to personnel working on top of the transformer, see clause 17.5.19 Guard Rail / Fall Arrest System.

All joints at manholes, hand holes and bushing openings shall be bolted and shall be provided with suitable gaskets and flanges to the approval of EIRGRID.

All joints at manholes, hand holes and bushing openings shall be bolted and shall be provided with suitable gaskets and flanges to the approval of EirGrid. For dismountable mechanical connections, the flange seal design shall be flat rubber gasket. Gasket arrangements shall be designed to prevent over-compression of the gaskets and ingress of moisture between the flanges.

Flat gasket seal shall be provided on all large oil/ air interfaces. Details of the proposed design of the flat gasket seals shall be provided and subject to acceptance by EirGrid.

A rubber gasket material shall be Viton Type high temperature rubber.

All bolts and nuts are to be waxed before final tightening to prevent seizing.

Asbestos shall not be used in any gasket materials, nor in any other part of the transformer.

The accessories shall be vandal-proof as far as possible to protect against the possibility of a major oil spillage due to vandalism.

Oil level indicators of the glass tube type shall not be used, inspection windows shall have easily removable metal covers to protect the glass, e.g. on tap changers, Buchholz and gas pressure relays. All accessories and protection devices shall be submitted to EirGrid for review and acceptance.

Corrosion protection shall apply to all accessories/ protective devices for environmental category CX – offshore type units only.

Capillary tubes for remote oil level monitors and top oil thermocouples shall be provided with stainless steel protection and PVC coating.

Anti-vibration mountings for tap changer mechanism box, transformer marshalling box, dial thermometers, etc. shall be rated for continuous exposure to sun, rain, frost, snow and oil.

The undercarriage shall be as follows:

- The main tank will be skidded into position and mounted on anti-vibration supports to reduce vibration transmission to the foundation. A skid base shall be provided to allow the transformer to slide along either axis on to the foundation.
- Anti-vibration material and appropriate supports shall be included in the scope of supply.

The transformer will be installed approximately 150 mm above the top of its foundation so that inspection/painting of the base is possible.

The arrangement for location of the transformer on the foundation shall be included in the overall dimensioned drawing to be submitted with the tender and in the final dimensioned drawings.

Where wooden anti-vibration or mounting materials are used then the wood shall be hardwood and shall be treated for long term environmental exposure.

17.5.2 Dimensional Requirements

17.5.2.1 400 kV Transformers

Refer to project specific requirements for restrictions relating to 400 kV transformer dimensions.

The overall dimensions of 400 kV transformers shall be such that they fit into an 'envelope' of dimensions 19000 mm L x 9000 mm W. These dimensions to be clarified at tender stage and design review as it may vary dependant on location of the substation.

17.5.2.2 275 kV Transformers

The only transmission station with 275/220 kV substations is Louth 275 kV, during the tender evaluation it will need to be confirmed that the transformers are suitable for installation in Louth 275 kV Substation.

17.5.2.3 220 kV Transformers

The overall dimensions of 220 kV transformers shall be such that they fit into an 'envelope' of dimensions 17300 mm L x 14700 mm W x 11000 mm H. These dimensions to be clarified at tender stage and design review as it may vary dependant on location of the substation.

To facilitate transportation, it is desirable that the height can be reduced to approximately 6000 mm e.g. by removal of the conservator tank.

17.5.3 Conservator Tank

All relevant parts of Clause 17.6.2 apply.

The conservator tank shall be in two separate sections, one serving the main tank and the other serving the tap change diverter switch compartment. The capacities shall be such as to accommodate the change in oil volume over the range of ambient temperatures specified under section 17.2

Each section shall have an oil level gauge so located that it can easily be read by a person standing at ground level. This oil level gauge shall be mechanically protected by a suitable metallic or polycarbonate shield. The gauges shall be graduated for temperatures of –10 °C, 0 °C, +15°C and +30°C.

In addition, remote indication of each oil level gauge will be provided at a location accessible at ground level, preferably next to the top oil thermometer in the marshalling cabinet. Details of the proposed remote indication of the oil level gauge will be provided with the tender.

Each section of the conservator shall be fitted with a float switch with low oil level signal contact. The float switch in the tap change diverter switch compartment will be set up so that up-to 50 litres of oil may be removed from the tap change diverter switch compartment for maintenance purposes without operating the low oil level signal contact. This will allow oil samples to be taken during maintenance for a period of up to 8 years without raising a low oil alarm.

A fixed pipe shall be brought to ground level and terminated with a valve to enable topping up in the event of oil loss without the need to switch the transformer out of service.

Where the conservator tank is mounted on or fixed to the main tank the design of the required support structure and its fixing to the main tank shall be such that the main tank will not be adversely effected by any additional mechanical loading or stress produced by the oil filled conservator tank and support structure under worst case outdoor environmental conditions as specified in XDS-GFS-00-001 110/220/400kV - Substation General Requirements.

Design calculations shall be provided to prove the support structure design is adequate.

17.5.4 Breathers

Each section of the conservator shall be fitted with maintenance free powered gel regeneration breathers which will be subject to the approval of the EIRGRID. As per clause 4 any proposed gels shall be EU REACH compliant. Desiccant type breathers are not acceptable. The breathers shall be located so that visual inspection can be performed at ground level. No valve shall be fitted between a breather and its tank compartment. Common flange sizes shall be used for connection of all breathers so that they may be easily replaced or interchanged.

The maintenance free breathers shall be provided with suitable control equipment housed in an IP 65 compartment if separate to the transformer control box. This compartment shall be located so that it is accessible from ground level. Voltage free contacts shall be provided for remote signalling of a fault or failure of the device. Multiplication of contacts by use of auxiliary relays is unacceptable.

Breathers shall be fitted with mechanical protection to prevent damage from accidental strike.

The bottom of the breather shall be at least 600 mm above ground level as it shall ensure that where the bund is not drained and filled with water, the breather is not covered. Where regenerative breathers are proposed with humidity sensors installed at the top of the device the Contractor shall design and fit additional rain shields over the top of the breathers to shield the sensor connection and cable gland from rainwater penetrating through glands positioned on top or at the side of the device.

The type of maintenance free breather to be used must be agreed upon by EIRGRID.

Service experience for this breather should be as per section 0 but with quantities supplied to be at least 500.

17.5.5 Oil Filtration

The transformer shall be designed and equipped for vacuum filling and oil treatment on site.

It shall be fitted with outlets and gate valves for the connection of oil and vacuum connections of an oil conditioning unit.

A minimum of four 50 mm connections shall be provided, one at top and bottom on each end of the main tank for the purpose of oil filtration. Each of the four valves shall have a 50 mm BSP female threaded connector to interface with the male connector from EirGrid oil conditioning plant and shall be fitted with a male plug. Flanged valves may be supplied provided they have cover plates fitted with a suitable 50 mm BSP female threaded boss and plug. Similar connections shall be provided on separate cooler banks if fitted.

Four additional valves of minimum size 50 mm BSP (DN 50 (minimum) or DN 80) shall be provided on the opposite tank wall to the oil filtration connections. Valves shall be routed direct into the transformer tank without right angles or ‘S’ bends to allow the insertion of partial discharge sensors for triangulation of any internal discharge activity.

One 100 mm connection shall be brought from the top of the conservator tank for connection to the vacuum equipment. Its valve shall have a NW 100 flange to interface with the connector from the EirGrid's plant and shall be fitted with a cover plate.

Care shall be taken when positioning the oil conditioning points to ensure a good flow of all the oil through the transformer, e.g. in the case of the main tank, one point shall be located high on the tank at one end and the other low down on the tank at the diagonally opposite end. The connection for the vacuum control switch shall be such as to facilitate efficient drawing of a vacuum, e.g. to the highest point of the conservator accessible from the ground.

The arrangement of the oil conditioning connections and the interface details shall be submitted to EIRGRID for approval.

17.5.6 Vacuum Withstand

The main tank, conservator, tap change diverter compartment, radiators and cable boxes shall all be capable of withstanding as close to full vacuum as is achievable, e.g. down to 1 kPa or better.

An interconnecting pipe, with a valve (normally closed), shall connect the main tank and the tap change diverter compartment to allow equalisation of pressure during evacuation. The valve shall be located such that it is accessible from ground level.

The vacuum withstand capability of the assembled transformer shall be proven as part of the evacuation procedure during first filling of the transformer with oil. Before admitting oil into the tank, the rate of pressure rise over a short period shall be measured and the transformer leak rate (kPa.Litres/Sec) shall be estimated. This test shall be witnessed by EIRGRID during factory or site acceptance testing.

A measurement of the tank deflection under vacuum shall be performed during the vacuum deflection test listed in clause 17.14.3.

17.5.7 Pressure Relief Device

Two pressure relief devices shall be fitted to the main tank and one shall be fitted to the diverter switch compartment.

Pressure relief devices shall be set to open on excess pressure and to reseal automatically without damage or endangering personnel.

The exact pressure at which the pressure relief devices are set to operate shall be stated by the Manufacturer.

Pressure relief devices shall be fitted with a volt free signal contact and trip contact.

Multiplication of contacts by use of auxiliary relays is unacceptable.

A blow-out of oil shall be directed downward into the transformer bund. Any ejected oil must remain within the oil tight transformer bund in which the transformer will be installed. Where a testing facility is included in the pressure relief device access to the testing device shall be possible without dismantling surrounding equipment.

Pressure Relief Devices shall have an ingress protection of IP 65 environmental protection designed for offshore environment. Additional rain or snow shields shall be provided as required to protect the device from long term moisture ingress if the device chosen by the transformer Manufacturer offers an inadequate level of protection.

Note the five-year corrosion warranty clause shall apply to all accessories. The Manufacturer shall choose accessories that offer a suitable level of moisture ingress protection and corrosion resistance.

17.5.8 Oil Sampling Devices

Oil valves shall clearly indicate whether they are in their open or closed positions and shall be fitted with appropriate blanking plates.

Oil sampling devices shall be fitted for taking oil samples from the top and bottom of the main tank and from the tap-change diverter oil compartment and separate cooler banks if fitted.

As far as practicable, oil valves and associated equipment shall be constructed and/or shielded so as to minimise the risk of unauthorised interference and vandalism.

All oil valves shall be provided with a means of securing them in the open and closed positions with padlocks as per clause 17.5.14 below.

All valves shall be suitably located for ease of access and maintenance.

Radiator butterfly valves shall be stainless steel.

Other types of valves shall be as required in the Technical Schedules and made of brass.

17.5.9 Oil Valves

Oil valves shall clearly indicate whether they are in their open or closed positions and shall be fitted with appropriate blanking plates.

As far as practicable, oil valves and associated equipment shall be constructed and/or shielded so as to minimise the risk of unauthorised interference and vandalism.

All oil valves shall be provided with a means of securing them in the open and closed positions with padlocks as per clause 17.5.14 below.

All valves shall be suitably located for ease of access and maintenance.

Radiator butterfly valves shall be stainless steel.

Other types of valves shall be as required in the Technical Schedules and made of brass.

17.5.10 Gas-IN Oil Monitor

The transformer shall be supplied with a Camlin TOTUS G9 on-line continuous gas-in oil incipient fault monitor.

The monitor shall be capable of carrying out the following functions:

- Transformer oil sampling
- Dissolved Gas Analysis (DGA) of all eight IEEE/IEC gases
- Diagnostics/Interpretation of insulating oil gas content. Preferably Doernenburg or Rogers Ratio method
- Diagnostics/Interpretation of paper insulation ageing and lifetime.
- Indication of oil moisture content

An inlet and outlet flange shall be provided on the transformer to provide an oil circuit to the gas monitor unit. These valves shall be located at points of good convective oil flow, remote from the tap changer and easily accessible.

The final location should be agreed prior to order.

The flange bringing oil to the DGA unit is typically located around two thirds above the base of the transformer and the flange returning oil to the transformer is typically located around one third above the base of the transformer. These valves shall be at least 0.5 m apart.

A brass 38 mm gate valve or similar approved standard valve shall be provided for isolating purposes between the tank and the monitor.

Remote access to the monitor shall be made available via GSM modem to be included with the monitor connected to a RS232 port. The monitor shall meet the relevant requirements of IEC 61850 ‘Communication Networks and Systems in Substations’.

The Gas-In Oil Monitor may be integrated with the Condition Monitoring Unit outlined in clause 17.7 subject to EIRGRID's approval.

Setup and commissioning of the monitor on site shall be performed by the Manufacturer of the gas in oil monitor, as part of the on-site assembly service.

17.5.11 Oil Piping

Non-metallic pipes for oil are not acceptable. The total oil system shall be of the flat gasket type designed to occupy the complete surface area of the flange. with no O-rings to be used anywhere.

17.5.12 Thermostat Pockets

In addition to the thermostats in the main tank top oil two spare thermostat pockets for measuring top oil temperature shall be provided.

17.5.13 Lifting Lugs

Lifting lugs shall be provided for supporting the core and windings and for supporting the complete transformer in its transport state.

17.5.14 Padlocking

Provision for padlocking of Kiosks, OLTC box, fanbox and valves shall be provided and a hole, approximately 7 mm diameter, shall be available for accepting padlocks with a shackle diameter of 30 mm, shackle length of 23 mm and 6.3 mm diameter cross-section.

17.5.15 Jacking Pads

Four jacking pads shall be provided near the corners of the transformer and approximately 500 mm above the lowest part of the tank. These pads shall be designed to take the complete weight of the transformer filled with oil.

Irons shall be provided to protect the tank when the transformer is being placed in position.

17.5.16 Hauling Eyes

Hauling eyes shall be provided on all sides of the transformer.

17.5.17 Earthing Terminals

Earthing terminals shall be provided close to each corner of the tank to facilitate earthing of the transformer using copper lugs each having 14 mm holes for fixing bolts.

Typical arrangements for earthing of the tank are illustrated in XDS-DGA-00-004 "General Arrangement Earthing Practice".

Earthing straps shall be provided from the main tank to all simultaneously accessible metallic parts including the tank cover, and across all flanged joints to ensure that all metallic parts are at equipotential.[14]

17.5.18 Core Earthing

The transformer shall be fitted with a covered box with IP65 environmental protection level, containing appropriately rated bushings to permit earthing of the core by a connection which is removable for testing. The core earthing bushing shall be rated for a minimum of 5 kV.

[14] These additional copper bonds are not shown in XDS-DGA-00-004.

17.5.19 Working at Height/Guard & Fall Arrest System

To facilitate assembly, commissioning, inspection and periodic maintenance testing, persons shall be required to access the tank cover and all devices located on the top of the transformer throughout its service lifetime. A ladder with a fall prevention cage shall be fitted to the side of the transformer as a permanent fixture to facilitate this. The ladder steps shall be designed and constructed with non-slip material on each rung. This ladder shall be lockable with a steel cover to prevent access to the top of the transformer during service. Where the ladder approaches the level of the cover a handrail shall protrude upwards a minimum of 1 meter beyond the level of the tank cover. Where electrical clearances permit, a fall protective gate shall be put in place at point of ascent/descent (of similar quality/safety to that of barrier system). The fall protective gate shall have a self-closing mechanism in place and clearly identified by yellow colour.

On the top cover of the transformer the Customer shall provide a barrier or guard rail system with permanent fixing brackets or sockets to erect the rail around the edge of the cover when required. The barrier shall be certified to minimum of Class A fall prevention standard per EN 13374. The guard rail shall be at least 950 mm high with an intermediate guard rail at approximately 470 mm high. A toe board of approximately 150 mm height shall also be part of the barrier/guard rail system to prevent tools or materials falling from the edge. The guard rail shall ensure that no gaps of greater 250 mm are present around the perimeter of the main tank cover when it is erected. The permanent fixing brackets or sockets shall be designed, and load tested with appropriate test certification to EN 13374. The barrier or rail shall not impede access to the top bushing for test purposes or to the lower capacitive tap test point which requires accessed for conditional assessment tests. It shall be painted yellow in colour to be distinguishable if to be disassembled before service.

Safe assembly of the barrier system shall be ensured by provision of anchor points to connect 150 kg capacity fall arrest lanyards. An anchor post shall be provided within 1 m distance of the ladder/handrail point on the top cover. This may be a permanent fixture, if electrical clearances permit, otherwise a baseplate shall be provided for the installation of a portable anchor post. This shall be a DURAHOIST™ TOTEM anchorage post or similar as proposed by the Customer. Additional anchor posts shall be provided on the top cover at suitable locations to allow personnel to install each anchor post while still attached to the previous post via a fall arrest lanyard. All permanent anchor points shall be certified to EN 13374:2013+A1:2018 and clearly identifiable (replaces EN 592).

Personnel shall be able to safely assemble the barrier at all edges while anchored to a post located at a distance suitable for the lanyard length. The Customer shall demonstrate by provision of a dimensioned drawing the location of all proposed anchor posts and locations that can be safely accessed while anchored to each post. The Customer shall advise the recommended length of the fall arrest or fall restraint lanyard to be used. A single length lanyard shall be used for the complete transformer therefore no point requiring to be accessed shall be located beyond the reach of an anchor post with the single length lanyard proposed. The Customer shall ensure the system provided also includes all associated necessary specific attachments and articles/materials in which to correctly use the system, for example runner connectors, latching pins or applicable karabiners.

A risk assessment and safe working procedure for the use of the working at height system and barriers shall be provided by the Customer in their submission and demonstrated through the provision of the dimensioned drawing outlined above.

Where other associated equipment, plant/machinery/articles etc. is required to facilitate the safe installation of the temporary systems this shall be clearly identified in the risk assessments and safe system of work (work procedures). The Customer shall also outline the inspection/testing requirements and frequency for the barriers/guardrail, anchors, fall arrest equipment and all other components of the system.

Sample diagrams of the anchor post and are shown below for information purposes only.

Figure 1 Anchor Post System

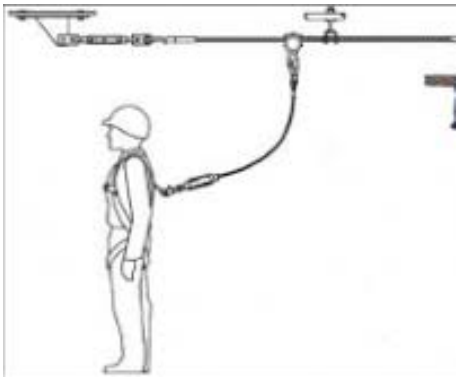


Figure 2 Horizontal Lifeline

17.6 Protection

17.6.1 Bucholz Relay

A double float and vane Buchholz relay shall be provided in the pipe connection from the main tank to the oil conservator tank. This relay shall be such that a slow release of gas closes an alarm circuit while a sudden pressure rise results in the operation of an alarm and trip circuit. It shall be fitted with a minimum of two trip and one alarm volt free contacts. Multiplication of contacts by use of auxiliary relays is unacceptable.

The Buchholz relay shall operate appropriate trip and alarm relays in the control cabinet. The gas release connection from the Buchholz relay shall be brought down (through copper tubing) to a gas sampling device which shall be accessible to a person standing at ground level. The test connection from the Buchholz relay shall also be terminated beside the Buchholz gas sampling device. Isolating valves accessible from ground level shall be provided on both of these connections.

The Buchholz relay and terminal box shall be an offshore type design to mitigate against moisture ingress, corrosion and failure for a minimum 20-year lifetime.

A 3-way valve shall be fitted between the main tank and the Buchholz relay to allow diversion of oil when maintaining and servicing the relay. A gate-valve shall be fitted in the pipe between the conservator tank and the Buchholz relay associated with the main tank to allow replacement without removal of oil. The design shall ensure that when the gate-valve is in the closed position expansion of oil due to heating does not create a risk of over-pressure which may weaken or damage the main tank. The proposed design incorporating a three-way valve between the Buchholz and main tank shall be provided by the Customer for review / comment by EIRGRID. The short circuit test shall verify that the gas pressure relay does not give any indication of having operated at short circuit currents less than or equal to the maximum possible short circuit secondary through-current.

The Buchholz relay shall be stable in operation so that it does not operate for faults external to the transformer.

17.6.2 Gas Pressure Relay

A gas pressure relay shall be mounted in the pipe leading from the tap-change diverter switch compartment to the conservator tank. This shall be fitted with two-volt free trip and alarm contacts. Multiplication of contacts by use of auxiliary relays is unacceptable.

The relay shall be suitable for use in offshore environments to mitigate against moisture ingress, corrosion and failure for a minimum 20-year lifetime.

A gate-valve shall be fitted in the pipe between the pressure relay and the associated conservator section. No other valves shall be fitted in this oil pipe. Design shall ensure that when the gate-valve is in the closed position expansion of oil due to heating does not create a risk of over-pressure which may weaken or damage

the tap-change diverter switch compartment or the main tank. The proposed design shall be reviewed and approved by EIRGRID during the formal design review.

The short circuit test shall verify that the gas pressure relay does not give any indication of having operated at short circuit currents less than or equal to the maximum possible short circuit secondary through-current.

17.6.3 Gas Sampling Device

The gas release connection from the Buchholz relay shall be brought down to a gas sampling device which shall be accessible to a person standing at ground level. The sampling device shall be labelled "Test".

A test connection from the Buchholz relay shall be brought to the gas sampling device, if suitable, or may be terminated beside it.

The gas sampling device shall have the following facilities:

a) Gas connection from the Buchholz relay through an isolating valve on the gas sampling device.

b) Coupling in the pipe connections to enable the device to be removed from the transformer.

c) Gas sampling valve at the top, with outlet approximately 3 mm diameter to make rubber tube connection. The outlet shall have a captive screwed cap.

d) Oil drain valve at the bottom with blanking plug.

e) The oil level in the device shall be visible from the front.

f) Isolating valves in both the gas sampling and test connections. These valves shall be accessible to a person standing at ground level.

17.6.4 Secondary Neutral Current Transformer

A current transformer (CT) shall be provided in a turret at the secondary neutral bushing to allow for earth fault protection.

The CT shall comply with XDS-GFS-035-001.

The CT secondary circuits shall be wired to the marshalling cabinet in accordance with XDS-GFS-07-001.

The ratio rated burden accuracy and accuracy limit factor of this CT shall be as stated in the protection specification.

17.6.5 400 kV Neutral Hall Effect Transducer

A hall effect transducer shall be provided in a turret of the 400 kV neutral bushing to monitor GIC DC flow in the earth 400 kV neutral. The transducer shall adhere to IEC 60688 and shall meet the following requirements:

- Measure and record DC current in the range +/- 100 A.
- Remove high frequency components leaving only DC component.
- Withstand 50 Hz AC short circuit current of a minimum of 15 kA peak for 1 s.
- Operate accurately between -20 ºC and 50ºC.
- Shall be sized appropriately to allow the transformer neutral earth conductor to be brought directly through it (i.e. similar to a ring CT). The neutral earth conductors(s) that will be used for the transformer neutral shall be specified.

17.7 Condition Monitoring System

The Customer shall quote for a price for optional inclusion of an on-line condition monitoring system with the transformer.

This system shall record, process and display transformer operating data and shall have the capability to store/log the historical data (measured and analysed) for a minimum of 10 years considering standard sampling rates. The system shall also meet the requirements of IEC 61850 to allow remote interrogation of the system.

The condition monitoring system shall be capable of generating easy to understand printable screen shots of the measured and deduced on-line and historical data in a user-friendly way.

The system shall aid operational staff to operate the transformer close to its thermal/current/ voltage limits taking into account thermal aging and avoiding critical hot spot temperatures. It shall also support advanced management of possible overload conditions.

The system shall provide detection of incipient faults at an early stage in order to avoid catastrophic failures of the transformer.

The fibre optic temperature indicator (FOWTI) shall be integrated into the condition monitoring system.

Data from the gas-in-oil monitoring system as described in clause 16.5.10. The gas-in oil monitor outlined shall be integrated into the condition monitoring system, subject to the EIRGRIDs approval to utilise the single GSM modem for remote communications.

The offered product shall be type tested in an independent and accredited laboratory.

Acquired / Measured Data:

- Top and bottom oil temperature
- Winding hot spot temperature(from the fibre optic sensors specified in 16.4.4)
- Ambient temperature
- Load current and voltage, active power and losses
- Voltage: Operational voltage and detection of transient over-voltages
- Cooling system Status of cooling fans
- OLTC: Tap Position capture, OLTC monitoring including contact wear and power consumption of the motor drive
- The Buchholz and gas pressure relay status
- Conservator tank oil level
- Oil Dissolved GA (connection to it)
- Bushing Partial Discharge Monitoring

Analysed quantities and functions:

- Apparent, active and reactive power, losses
- Load factor
- Overload capacity, emergency overloading time when overloading
- Sample and hold of transient over-voltages, number of transient over-voltages, last transient over-voltage
- Over-currents and short circuit currents
- Moisture in paper
- Paper insulation ageing and life-time consumption acc. to IEC 60076-7
- Calculate the winding hot spot temperature (IEC 60076-7) and compare with measured values in real time

- Bubbling temperature and according to safety margin
- OLTC monitoring: Contact wear, inrush time, switching time, number of switching operations of OLTC, number of switching operations of pre-selector, number of switching operations of selector, diverter switch current during switching operation, sum of switched load current, maximum power consumption of sectors 1, 2, and 3, switched energy, assessment of mechanical quality of tap changer, number of OLTC operations until service, sum of switched load current until service
- Cooling Unit: cooling efficiency (Rth), running time of cooling pumps and fans

The CMS shall also carry out the following functions:

- Cooling system control up to at least 2 stages (as per clause 16.4.) based on temperature data from the fibre optic sensors
- The system shall include analogue and digital inputs and digital outputs as required
- Calculation of winding hot spot temperature and compare with measured values in real time
- System alarm diagnostics
- Data logging: 10 years at standard sampling rates
- Simulation of load factor, hot spot temperature, aging rate, losses, moisture in insulation paper
- Generate reports / create protocols, periodically or on demand, including status information about the transformers and its main components

Provision shall be made for further monitoring of:

- Partial discharge using UHF, acoustic or electrical method
- Bushings: Change of capacitance, on-line capacitance, capacitive displacement currents

Additional sensors and associated features and integration shall be provided as required to capture the above information and interface it to the CMS.

The CMS shall record and store the captured data on removable media (e.g. micro SD card, USB, removable hard drive etc.), process and display transformer operating data and transmit data for remote monitoring via GSM modem.

The system shall meet the relevant requirements of EN 61850 ‘Communication Networks and Systems in Substations’ and support industry communications standards including Modbus to enable it to communicate with third party data and the station SCADA system.

The system shall include analogue and digital inputs and digital outputs as required.

The system shall provide Cooling system control up to at least 2 stages (as per clause 17.4) based on temperature data from the fibre optic sensors.

Provision shall be made for:

- Calculation of winding hot spot temperature and compare with measured values in real time
- System alarm diagnostics
- Data logging (Manufacturer to advise of unit capabilities)

17.8 Terminal Type

17.8.1 High Voltage Connections

Primary and secondary phase connections shall be brought out in one of the following ways, as required by project specific documentation:

a) External bushings for AIS connection

b) Single phase cable end boxes

Single phase oil/SF6 bushings for GIS bus-duct connection

Refer to project documentation for clarification of the required method of connection on each side.

Neutrals shall be brought out to external bushings.

The tertiary winding in all cases shall be closed and earthed outside the tank. Two condenser type bushings shall be provided to which the open ends of the delta shall be connected. The necessary shorting and earthing straps shall be supplied with the transformers. The two other terminals of the delta shall be accessible inside the tank for future connection to reactive power compensation equipment

17.8.2 Outdoor Bushings

All bushings shall comply in general with IEC 60137.

The bushings shall be Resin Impregnated Paper (RIP) or Resin Impregnated Synthetic (RIS) condenser type bushings with silicone rubber external insulation.

Tertiary bushings shall be condenser type. Porcelain bushings or cap type shall be not permitted.

Each bushing shall be equipped with a measuring tap for the measurement of the capacitance and power factor of the bushing. The insulation quality shall be such that the % power factor of the tap does not exceed 0.5 %.

The minimum value of cantilever withstand load for 110 kV bushings shall be 2 kN regardless of current rating as per IEC 60137 – heavy load level II

The minimum value of cantilever withstand load for 220 kV and 400 kV bushings shall be 2.5 kN regardless of current rating as per IEC 60137 – heavy load level II

The minimum design clearances in air shall be as indicated in Table 13.

Table 17 Minimum Clearances

Voltage (kV)	Clearance (mm)		
	Ph-Earth	Ph-Ph	HV-LV
400	4100	4750	5940
275	2400	3100	3100
220	2400	2700	2400[15]
110	1100	1100	-

The minimum clearances for 10.5 kV tertiary windings shall be 180 mm. Clearances for other voltages shall be agreed by EIRGRID.

Lower minimum external clearances in air will be accepted for the bushings if, as part of the transformer assembly, they successfully pass the tests which prove the insulation withstand requirements of the transformer. However, the bushings shall be arranged to facilitate conductor connections complying with the above clearances.

The insulation withstand levels shall be as specified in clause 17.2.3.

The Reference Unified Specific Creepage Distance (RUSCD) for the phase to earth insulators shall be 53.7 mm/kVL-L in accordance with IEC 62271-1 and EN TS 60815 requirements for very heavy pollution level (31 mm/kV phase to earth).

The RUSCD shall be corrected for insulator diameter using the method given in IEC TS 60815-2.

[15] The required clearance is determined by the primary voltage. Therefore, this figure is only applicable to 220/110kV transformers.

The tenderer shall also state the profile factors (as defined in IEC 60815-3) for the proposed insulator design in the Technical Schedules.

Terminals shall comply with EN 62271-301 and shall be of flat aluminium with hole/holes of 14 mm diameter at 50 mm centres. Stud type terminals may be accepted.

Transformer terminals shall be rated for the overloads specified in section 16.2.1 and shall facilitate connection to external bay conductors [16].

The bushings shall be identified in accordance with IEC TR 60616 as follows:

An observer facing the primary side of the transformer shall read, from left to right

Primary Side	1N	1U	1V	1W
Secondary Side	2N	2U	2V	2W

The position of the primary and secondary neutral bushings shall be such that connection of the phase conductor to the AIS phase bushings will not compromise the clearance limits stated above. Alternative positioning of the primary and secondary neutral bushings will be considered if the supplier can demonstrate sufficiently that the required clearance limits can be achieved.

The positioning of the neutral bushings shall be such that connection of the primary neutral to earth and connection of the secondary neutral to a neutral earth switch located on the secondary side of the transformer is achieved in a straight-forward manner.

The open delta tertiary bushings shall be marked in accordance with IEC 60616.

Terminal markings shall be clearly and permanently shown on the cover plate and on the side walls of the main tank below each bushing location. They shall be visible from ground level.

Refer to 16.2.9 for partial discharge levels for bushings.

17.8.3 Cable Boxes

Where specified, phases shall be brought out to single cable end boxes.

A drawing of each box shall be provided by the Supplier to define the interface and describe the division of responsibility between the suppliers of transformer and cable, i.e. for supply of fixings, gaskets etc. This drawing shall be formally signed off by the two suppliers.

The size and type of each cable will be advised to the successful Tenderer.

The housing shall be arranged for vertical entry of the cables from the bottom. The height of the take-off position above ground level should be at least 3 m so as to permit convenient connection / disconnection of cables. Cable connection shall be centred as much as possible on the main tank to allow for easy cable connection from the cable ducts.

Connex size 6 sockets for plug in cable connections shall be utilised where the cable conductor size permits their use.

The assignment of responsibilities in the area of transformer / cable interface shall be generally in accordance with IEC 62271-209. If a corona shield is required, then it is in the transformer Manufacturer's supply.

17.8.4 GIS Direct Connection on Transformer

The assignment of responsibilities in the area of GIS switchgear/transformer interface shall be agreed with both Suppliers and EIRGRID and shall be in accordance with IEC Publication IEC TS 61639

[16] Refer to the project SLD for bay ratings to be achieved by external conductors.

The Customer shall co-ordinate the design of the transformer bushing housing with the transformer and switchgear suppliers. Consideration shall be given to vibration of transformer, settlement of the transformer foundations and different rates of thermal expansion of transformer and GIS housings.

If the earthing systems of the transformer and GIS are isolated from each other, the open connections shall be protected against over voltages.

17.9 Noise

The noise levels of transformers shall be guaranteed by the Supplier and shall be measured in accordance with EIEC 60076-10 at 100% Ur.

The guarantee shall be for sound pressure level at 2 m away from the principal radiating surface with all forced air cooling equipment and any oil circulating pumps in service. The A-weighted normal level shall not exceed the following values [17]:

Table 18 Noise Levels

Voltage Ratio	Power (MVA)	Max sound pressure level (LpA) at 2 m with all coolers in service (dBA)	Load noise test as per IEC 60076-10
400/220	500	78	<no load test
400/110	500	78	<no load test
275/220	600	78	<no load test
220/110	250/ 125	70	<no load test

In addition, there shall be no dominant tone in either transformer or cooler noise. This shall be demonstrated by performing a third octave band sound pressure level measurement.

17.10 Loss Capitalisation

Transformer losses shall be capitalised at the rates specified in the project specification. Losses will be capitalised at these rates and taken into account when tenders are being evaluated.

At 100% rated load the fan and pump loading to be capitalised at Copper Loss (Load Loss) rates is the total fan/pump load at rated load less the fan/pump load at up to 60 % of rated load. The fan/pump load at up to 60 % rated loads is deemed to be on continuously and is hence capitalised at Iron rates. A separate figure shall be provided for stage 1 and stage 2 fan and pump load losses. Stage 2 fans and pumps shall have the same efficiency as stage one fans and pumps.

At 100 % rated load the fan and pump loads shall be multiplied by the Copper (LOAD) Loss rate according to the enquiry letter and added to the winding/copper losses quoted and iron (NO-LOAD or CORE) losses to provide total cost of transformer operation.

The losses shall be measured during the routine tests. A tolerance of +5.0 % will be allowed on the guaranteed component losses. In the event of either the no-load Iron losses or Copper load loss exceeding its guaranteed values as stated in the Technical Schedules, the relevant rate specified in the enquiry letter shall be applied to the excess (over the guaranteed component losses) and the resulting amount shall be deducted from the Contract Price.

There is no additional price or increase if measured losses are less than the guaranteed values.

Value of losses, by which each transformer price is to be reduced, is calculated as follows:

$$L(i) = A(Wanl(i) - Gnl) + B(Wall(i) - Gll)$$

[17] Transformer noise level shall be reduced further, and/or noise mitigation measures shall be provided as required to meet planning requirements. Refer to XDS-GFS-00-001 for further requirements.

Where:

L(i) = Total value of losses by which price of Transformer (i) is to be reduced

A = Capitalisation value of No Load Losses in €/kW as provided by EIRGRID

B = Capitalisation Value of Load Losses in €/kW as provided by EIRGRID

Wanl(i)= actual value of No Load Losses in kW as measured on the particular transformer

Wall (i) = actual value of Load Losses in kW as measured on the particular transformer

Gnl = Guaranteed No Load Losses in kW as stated in Tender

Gll = Guaranteed Load Losses in kW as stated in Tender

There is no bonus if measured losses are less than those listed in the tender.

In addition, the transformer measured losses shall be within the maximum tolerances allowed by IEC60076, and also with (EU) No 548/2014

Note that the Transformer must be designed in accordance with the EU EcoDesign Directive 2009/125/EC per Tier 2 levels applicable from July 2021 on.

17.11 Internal Design Information

To assist with fault diagnosis inside the transformer, the Supplier shall provide drawings showing dimensions, positioning and fixing arrangements of the core, windings, leads, oil directing devices, shields and other main features which could distort or move during internal faults. A brief description of materials used in the core, windings, insulation, shielding, lead supports, winding formers and conductor spacers shall be provided together with a photograph of the active parts before they are tanked. This information shall be included in the technical record folders, i.e. the OEM manual.

The Customer shall provide details of insulation margin percentage to which the transformer is designed.

The Contractor shall provide details of insulation margin percentage to which the transformer is designed.

A graph of the heat rise for each overloading indicating the pre-load condition, and the rise in temperature with time to the final loading allowed, with the loading condition shown in Amps shall be provided. The overload graphs shall be provided for ONAN, , ONAF and at Power Factors of 0.9 and 1.0- for input and output loadings.

17.12 Transformer Oil

The insulating oil shall be new, unused mineral oil free from potentially corrosive sulphur to IEC 62535. See also REACH Regulation (EC) No 1907/2006.

The tender shall advise if transformers are to be transported to site without oil or with just the active part covered in oil.

If the transformer is to be transported without oil:

- The Manufacturer shall advise on precautions that will be taken to protect the active part against humidity and advise on the maximum permissible period that the transformer may be left without oil covering the active part.
- Vacuum testing of the tank shall be carried out in the factory prior to shipping.

The method of transport of the transformer to site/ storage facility shall be submitted to EIRGRID for approval before the transformer leaves the works.

The Manufacturer shall ensure that at all stages of manufacture, test and installation of the transformer and insulating oil shall be free of all contaminants including cross-contamination by other insulating fluids.

The oil in all transformers shall be tested and certified ‘no detectable Silicon’ and PCB < 1ppm. Such certification shall be submitted to EIRGRID for approval prior to shipment of the transformers.

Details shall be supplied of the Test regime and procedures which will ensure that contaminated oil will not be put into the transformer at any stage.

17.13 Markings, Labels and Rating Plates

17.13.1 General

All signs, labels, rating plates, information plates, diagram plates and instructions shall be clear, indelible, corrosion proof, in English and clearly visible to a person standing at ground level.

Rating and information plates shall be made from grade A4 stainless steel as per ISO 3506-1 (AISI 316).

Labels and safety signs shall be provided for in accordance with XDN-LAB-STND-001 “Station Design Standard 110/ 220/ 400 kV Station Signage”

A QR code containing the relevant information in a digital format shall be proposed in addition to the engraved plate as a separate plate or on the rating plate itself.

The Customer shall submit drawings of all labels and plates for EIRGRID approval. The exact position of all plates will be agreed during the design review.

17.13.2 Rating Plate

A rating plate in accordance with IEC60076-1 shall be securely attached to each transformer. This shall include all the information as stated in Clause 8.2 and 8.3 of IEC60076-1.

This plate, or another of similar construction, shall also include the following information:

- Measured value of winding resistance at all tap positions corrected to 20 °C.
- Measured values of winding capacitances and dielectric dissipation factor (tan delta or percentage power factor corrected to 20 C) values to be given for all windings to ground and between windings.
- Measured values of impedance voltage at principal tap and at both extreme taps corrected to 20°C.
- Short Circuit design value - short circuit design ratings of all windings to be detailed on the rating plate, including tertiary winding rating. Three phase and single phase ratings to be detailed for all windings.
- The gross in-service weight of the complete assembly, the weight of the active parts, the gross weight and volume of oil, the weight of copper content, the weight and volume of oil in the tap changer unit.
- Other information as required by EU No 548/2014 should also be included

17.13.3 Selector Compartment Information Plates

Information plates for the selector compartment shall be fitted to the main tank.

These plates shall be located on the main tank and shall be clearly visible to a person standing at ground level. The exact position of these inspection plates shall be agreed during the design review.

These plates will indicate the number of operations after which inspection will be required on the selector compartment and any other relevant information.

17.13.4 Locations of Oil Valves and Air Release Clocks

A plate showing the locations and normal positions of all valves and air release cocks or plugs shall be provided. This plate shall incorporate a warning to operators to refer to the Maintenance Instructions before applying vacuum treatment to the tank.

17.13.5 Gas Points

Labels shall be attached to all gas release, gas sampling and Buchholz test points stating the name of the associated oil compartment.

17.13.6 Direction of Rotation

The direction of rotation of operating handles or motors and fans shall be clearly marked in red arrows and text on or beside each item.

17.13.7 Control and Auxiliary Equipment

All control and auxiliary equipment including equipment boxes and their contents, cooling fans, pumps etc. shall be clearly labelled.

Cooling fans, pumps and their associated MCBs shall be labelled with matching numbers.

Refer also to XDN-LAB-STND-001 “Station Design Standard 110/ 220/ 400 kV Station Signage”.

Any device, cover, auxiliary relay etc. which can be removed shall be labelled on both the removable part and the back plate / base where the device is located.

17.13.8 HV Bushings

In the case of bushings rated 110 kV and higher, the name-plate shall, in addition to the information required by IEC 60137, include the measured values of capacitance (C1 and C2) and dielectric dissipation factor between high voltage terminal and test tap and between test tap and earth, stating the test voltage applied.

17.14 Tests

17.14.1 General

Tests shall be carried out on the transformer as detailed herein and generally in accordance with IEC 60076. EIRGRID reserve the right to refuse to accept a transformer if test results do not comply with the standards and values specified and the information and data given in the Technical declaration .

Tests shall be carried out with the transformer, including conservator, fully erected and in the service condition. Any deviation to this arrangement to be approved by EIRGRID.

Before and after routine testing of a transformer, samples of oil shall be taken from the transformer and analysed for dissolved gases using the procedures specified in IEC 60567 and IEC 60599. Results of the analysis of gases dissolved in the oil shall be immediately submitted to EIRGRID and included in the Test Report.

Type and routine tests shall be performed as specified in the following sub-clauses. Full details of the proposed methods of testing including connection diagrams shall be submitted by the Customer for approval at least one month before testing.

Type and routine test results shall be furnished for bushings, tap-changer, cooler motors, Buchholz relays and other ancillary equipment. EIRGRID may require that some of these tests be repeated if they do not meet the requirements of this specification, the relevant national and international standards.

The short circuit test shall also verify that the Buchholz and Gas Pressure relays do not give any indication of having operated in response to external short circuit currents.

EIRGRID reserves the right to witness type, special and/or routine tests or visit the factory during the manufacture of any or all transformers. The Customer shall provide a minimum of 3 weeks’ notice of tests and manufacturing programmes.

In addition, the following shall be performed:

(a) Transformers shall not be dispatched until type test certificates have been reviewed and accepted.

(b) The programme of type tests shall be advised at least three weeks in advance to permit witnessing.

(c) All routine tests prescribed by this Specification shall be included in the offer. Prices for type tests and special tests shall be quoted as separate items.

(d) Copies of any type tests results already carried out on the transformer model shall be supplied with the offer.

(e) The Employer as the asset owner shall be free to reject transformers for which the test results do not meet the values specified.

(f) Tests shall be carried out in accordance with the latest edition of IEC Publication 60076 (see ALL PARTS: 2015 OC).

(g) Routine tests shall be carried out on all transformers. The type tests required shall be stated at the time of ordering.

Refer also to XDS-GFS-00-001 110/220/400 kV Substation General Requirements.

17.14.2 Type Tests

General requirements for type tests are specified in the latest revision of EIRGRID functional specification XDS-GFS-00-001 '110/220/400 kV Substation General Requirements'.

All transformers offered shall have been fully type-tested in accordance with the tests listed in the relevant IEC Publications and the results shall demonstrate, in relevant respects, the capability to meet the requirements of this specification.

These type tests shall have been carried out at an independent and accredited testing laboratory or alternatively shall have been witnessed by a representative of an independent and accredited testing agency or other independent witness.

Certificates/Reports containing full details of type tests shall be submitted to EIRGRID for review.

Certificates/ Reports may be considered as an alternative to carrying out type testing. The Tenderer should however, in all cases submit a priced option to conduct Type Tests.

EIRGRID reserve the right to request further testing to be carried out at an independent testing station. All proposals are subject to this condition.

Such testing may be witnessed by EIRGRID, or a nominated representative.

The equipment available for type tests shall be identical in all respects to that to be supplied to EIRGRID.

In the event of a type test failure, EIRGRID will not be charged for any additional type tests.

The following shall be regarded as type tests and shall be carried out on one transformer of each rating:

(a) Test of temperature rise. This test shall be carried out on tap with maximum loss unless otherwise agreed by EIRGRID. Temperature rise shall be measured at ONAN rating and full rating (ONAF or OFAF). The power input to the transformer during the temperature rise test shall include a quantity corresponding to the no-load loss, calculated at voltage of 1.1 times the rated voltage of the transformer. The direct winding temperature equipment as per clause 16.4.4 shall be utilised during this test. Correction to 20°C ambient shall be performed using the directly measured value. Average winding temperature may be measured by the Contractor as set out in IEC 60076-2 for comparison against direct measurements only. In event of any conflict of results the direct measurement value shall apply.

An oil sample for DGA shall be taken before and after each temperature test. The rate if increase for each of the key gases averaged across the duration of the temperature rise test shall not exceed the values in the table below.

Table 19 Dissolved Gas Analysis Maximum Rate of Increase

Gas	Max Rate of Increase (ppm/hour)
Hydrogen (H2)	1.2
Methane(CH4)	0.35
Ethylene (C2H4)	0.1
Ethane (C2H6)	0.13
Acetylene (C2H2)	0.01
Carbon Monoxide (CO)	4
Carbon Dioxide (CO2)	22

(b) Temperature rise testing shall be carried out to demonstrate the short and long-time overload ratings as required in clause 16.2.1 and 16.2.11. Winding temperature (hotspot) shall be directly measured via fibre optic sensor embedded in the winding and recorded in the test report. Correction to 20°C ambient shall be performed using the directly measured value. Average winding temperature may be measured by the Contractor as set out in IEC 60076-2 for comparison against direct measurements only. In event of any conflict of results the direct measurement value shall apply.

(c) Measurements of open-circuit and short-circuit zero phase sequence (ZPS) impedances of the HV and LV windings, i.e. ZPS of HV winding with LV open, ZPS of HV winding with LV shorted to neutral, ZPS of LV winding with HV open and ZPS of LV winding with HV shorted to neutral.

(d) Measurement of power taken by fan motors and pumps

(e) Short Circuit Withstand test, where required, as per clause 17.2.5 above. Where this test is conducted it should include a demonstration that the Buchholz relay does not operate due to an external short circuit.

(f) Noise Level Test measurement, in accordance with IEC 60076-10 using a precision sound level meter conforming to that standard. The transformer shall have the radiators fitted during tests. The test shall be arranged so that the difference between the background noise and that resulting from the combination of the equipment and background levels is at least 7 dB. 1/3 octave sound levels shall be measured as part of this test and recorded.

(g) Verification of IP rating capability on all enclosures.

(h) Check of non-retention of water on the tank cover.

(i) Type testing of painting and corrosion protection system as per clause 17.16 above.

(j) Lightning impulse test the impulse test shall be carried out in accordance with IEC60076-4. The impulse series of shots shall be applied to all terminals. The insulation of any windings not undergoing test shall be adequately rated to cope with possible transferred overvoltage's from windings under test without the need for voltage limitation devices.

The tests shall include the following:

- Full-wave impulse voltage withstand test. The applied voltage shall be the relevant lightning impulse voltage specified in clause 16.2.3.
- Chopped-wave impulse voltage withstand test. The applied voltage shall be 110 % of the relevant lightning impulse voltage as per IEC 60076-3.
- In the case of line terminals, Tests 1 and 2 shall be applied as follows and in the sequence indicated:
- One reduced full impulse (calibration, 50 to 75 %)
- One 100 % full impulse
- One or more reduced chopped impulse(s)
- Two 100 % chopped impulses
- Two 100 % full impulses

- In carrying out the above tests, the two extreme taps and an interposing tap shall be used, with each of the three phases being tested on a different tap.
- In the case of neutrals, Test 1 only shall be applied as follows in the sequence indicated:
- One reduced full impulse (calibration, 50 to 75 %)
- Three 100 % full impulses

  The neutral shall be impulse tested at the relevant 20 kV insulation level as per clause 16.2.3 with the off-load tap-changer set to corresponding position 2 (20 kV voltage ratio). Per IEC 60076-3 the peak value of the impulse voltage for the neutral terminal is the same as the line terminals (uniform insulation). As per 7.3.1.3 of IEC 60076-3 the impulse test on the neutral (LIN) shall be carried out at the maximum turn ratio with respect to the winding to which it is connected.

(k) Partial discharge test.

This test shall be carried out using a broad band instrument to prove compliance with the requirements of the sub clause on Partial Discharge.

(l) Vacuum test to prove compliance with clause on Vacuum Withstand including measurement of tank deflection.

(m) Insulation dielectric voltage test to all Auxiliary / Control Circuits.

17.14.3 Routine Tests

The following shall be regarded as routine tests and shall be performed on each transformer in the following order:

(a) In the case of bushings rated 52 kV and higher, the values of capacitance and % power factor shall be measured between high voltage terminal and test tap with 10 kV applied, and between test tap and earth with 1 kV applied.

(b) Measurement of winding resistance

(c) Voltage ratio measurement and check of vector group.

(d) Lightning impulse test

1 Full wave impulse voltage withstand test. The applied voltage shall be the relevant lightning impulse voltage specified in the clause 2.04 on RATED INSULATION LEVELS.

2 Chopped wave impulse voltage withstand test. The applied voltage shall be 110 % of the relevant lightning impulse voltage.

In the case of line terminals, Tests 1 and 2 shall be applied as follows and in the sequence indicated:

- One reduced full impulse (calibration)
- One 100 % full impulse
- One or more reduced chopped impulse(s)
- Two 100 % chopped impulses
- Two 100 % full impulses

In carrying out the above tests, the two extreme taps and another tap to be selected by agreement between the Employer and the Contractor shall be used, with each of the three phases being tested on a different tap.

In the case of neutrals, Test 1 only shall be applied as follows in the sequence indicated:

- One reduced full impulse (calibration)
- Three 100 % full impulses

(e) Switching impulse test on 220 and 110 kV terminals.

The applied voltage shall be the relevant switching impulse (peak) voltage specified under RATED INSULATION LEVELS.

(f) Separate source voltage withstand test.

The applied voltage shall be the relevant power frequency AC withstand (separate source) voltage specified under RATED INSULATION LEVELS.

(g) Induced over-voltage withstand test

The applied voltage shall be the relevant power frequency AC withstand (separate source) voltage specified under RATED INSULATION LEVELS.

(h) Partial discharge test.

This test shall be carried out using a broad band instrument to prove compliance with the requirements of the sub clause on PARTIAL DISCHARGE.

(i) Measurement of the impedance voltages on all taps.

(j) Measurement of the load loss[18].

(k) Measurement of no load loss and no load current, including measurement of harmonics.

(l) Measurement of capacitances, dielectric dissipation factor or percentage power factor of windings (to ground and between windings).

(m) Tests on load tap changer (fully assembled on transformer) in accordance with EN 60076. A dynamic resistance measurement test shall also be performed and shall be carried out using a DV Power instrument or similar.

(n) Noise level measurement, in accordance with EN 60076-10 using a precision sound level meter conforming to that standard.

(o) Repeat of Test (a) above. In the case of bushings rated 52 kV and higher, the values of capacitance and % power factor shall be measured between high voltage terminal and test tap with 10 kV applied, and between test tap and earth with 1 kV applied.

(p) Applied voltage test to all auxiliary circuits.

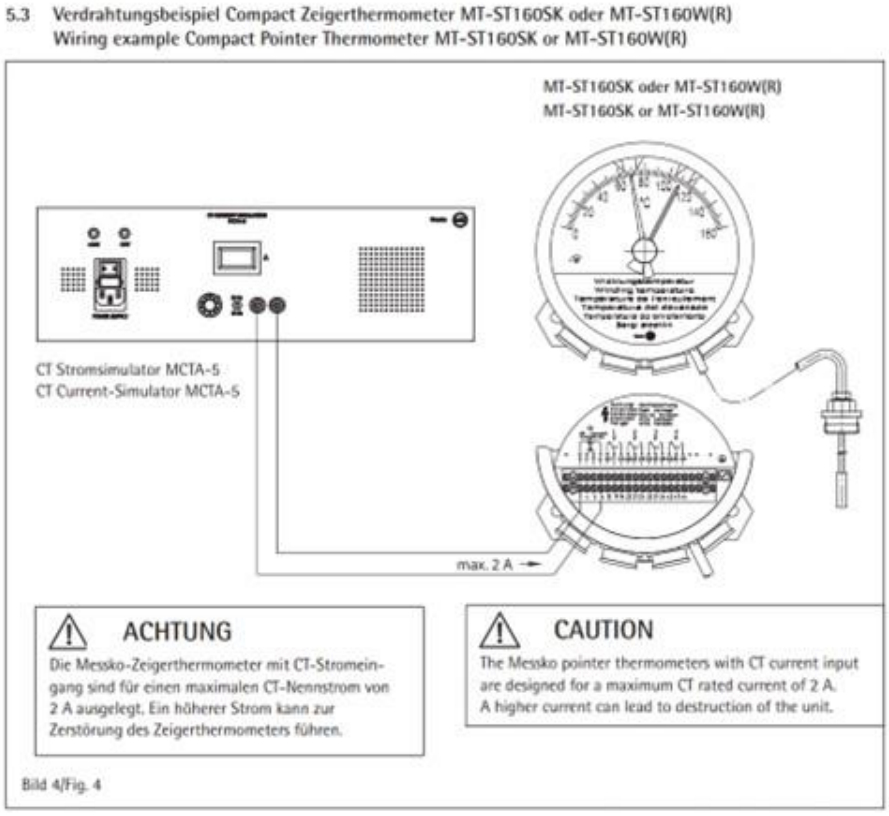
(q) The actual creepage distance over external insulation on a representative sample of all H.V. equipment prior to despatch from works. Measured values shall be included in the routine test report.

(r) Measurement of frequency response analysis using the sweep frequency method. Test method to be agreed in advance with the Employer.

(s) Testing, setting and calibration procedure requested for WTI (Winding Temperature Indicator):

- Set the compact WTI temperature gradient according to the gradient of the tested transformer, using standard heat run test data and overload heat run test data,
- Connect CT simulator to the WTI according to schematic below and inject the current to the Compact WTI :

[18] Note: In the event of losses exceeding their tolerance or differing from type tested unit by more than 5 %, the Contractor shall investigate the possible cause and confirm the cause to the Employer. The integrity of the core shall be confirmed before shipment of the transformer



- Use a calibration bath and set it to the desired temperature.
- Inject the current and put the thermometer bulb into the calibration bath correctly, the hot-spot gradient will “add” to the oil temperature in the calibration bath and allows the WTI values to be verified.

In addition, the following shall be performed.

(t) Pressure test on the main tank.

(u) Vacuum test to prove compliance with clause on Vacuum Withstand.

(v) Testing of the integrity of all welds via NDT leakage current, dye-penetration, Ultrasound A-type scan or other agreed method.

(w) Leakage tests on gaskets.

(x) Routine testing of the painting and corrosion protection system as per section 2.11.02 above.

17.15 Enclosures

All outdoor LV equipment enclosures shall have an ingress protection of IP654 or greater in accordance with IEC 60529 and shall meet the painting and corrosion protection requirements in section XDS-GFS-17-00.

Enclosures shall be fixed to the transformer using anti-vibration mountings and shall be at a convenient height and location for standing operators.

All cables shall enter the enclosure vertically from below and shall be appropriately glanded at their point of entry.

As a minimum, enclosures shall be equipped with the following:

a) A separate removable gland plate to take a minimum of eight 25 mm diameter holes for external cabling.

b) A hinged door fitted with retainers to allow fixing in the open position and suitable for locking with a padlock.

c) External label on front door. Refer to drawings XDN-LAB-STND-001 for details.

d) Labelling of internal equipment, terminals, terminal blocks etc. as appropriate.

e) A 230 V, 50 Hz anti-condensation space heater which shall be controlled by means of a humidistat and a cut-out thermostat with an adjustable operating range, to prevent overheating.

f) The live parts of heaters shall be enclosed with a minimum ingress protection of IP2X.

A fixed internal lamp controlled by a door switch.

g) Terminals with a minimum of 10 % spare.

A drawing, fixed to the inside of the door, on robust material, indicating the connections within the box.

h) A minimum ingress protection of IP2X for any shafts or moving parts outside the mechanism.

i) Electrical protection of motor and Control Circuits

j) Earthing facilities

Internal earth bars shall be provided as described in XDS-GFS-07-001 and shall be equipotentially bonded to internal metallic parts by copper conductors of at least 6 mm^2.

An appropriately sized earth bar shall be provided by the Customer to facilitate all cable earth sheets, bonding connections etc. within the marshalling kiosk(s). The earth bar shall be connected to an earthing lug / point located external to the marshalling kiosk(s). This earth lug can also serve as the main earthing point for the marshalling kiosk(s). The earthing point shall facilitate the connection of the marshalling kiosk(s) to the station earth grid. All CT neutral connections shall be made off securely to the earth bar located within the marshalling kiosk(s) via appropriately sized ring lugs and bolts. Pinch / clip-on type connections for CT neutrals shall not be permitted.

Overall earthing and bonding towards external metallic parts shall be provided by bonding to the tank structure. Refer also to clause 17.5.17 for overall earthing requirements.

17.16 Painting and Corrosion Protection

Corrosion of both ferrous metals and of aluminium and aluminium alloys is a particular problem in Ireland.

All exposed ferrous parts, including nuts and bolts, shall be hot-dip galvanised to comply with EIRGRID specification XDS-GFS-18-001, “Hot Dip Galvanising of Iron and Steel Other Than Wire”.

The Customer shall state clearly in the schedule of Corrosion Protection (part of Technical Schedules) the corrosion protection applied.

Experience has proven that extreme precautions are necessary (because of the high humidity and salty costal environment) to prevent the aggressive ingress of moisture between flange plates, around gaskets and O-rings and at insulator/flange interfaces. To prevent water ingress all such areas shall be filled or coated with a suitable wax, grease (e.g. Tactile 506) or RTV silicone. This may be applied at the factory or during assembly on site. Painting and Corrosion protection requirements shall apply to all devices bought from sub-suppliers e.g. Buchholz relay, Pressure Relief Devices.

All materials shall be chosen to ensure galvanic compatibility and resistance to galvanic corrosion where different alloys or metals are in contact with each other. For offshore or C5-VH environment pollution classification there shall be a maximum of a 0.15 V difference in the ‘Anodic Index’ between materials used. Aluminium alloys of the 2000 series are not suitable for use in Ireland due to accelerated corrosion occurring with the high copper content of this alloy and shall not be permitted. Care shall be taken to ensure mechanism boxes or other devices are selected of a suitable alternative alloy type.

With the exception of the main tank cover which shall be fully welded in position, as per clause 17.5.1, flat gasket seals are required on all large oil/air interfaces. Details of the proposed design of the flat gasket seals shall be provided and subject to acceptance EIRGRID.

The Customer shall protect all exposed points in their equipment at which aluminium or aluminium-alloy parts are in contact with or in close proximity to other metals and shall ensure that air and moisture are excluded from such situations. All aluminium or aluminium alloy parts shall be anodised with painted or equivalent finish. The coating/ finish proposed shall be agreed upon and approved by the EirGrid before being used.

The painting and corrosion protection system shall as a minimum meet the requirements of this clause and all its sub-clauses and shall be approved by EIRGRID. The Customer may provide as an option an enhanced Painting and corrosion Protection system which exceeds the requirements set out in this specification, but which makes a material difference to corrosion resistance and lifetime of paintwork.

All external surfaces shall be primed and finished in grey colour RAL 7033.

This 'Painting and Corrosion Protection' clause shall apply to all parts of the transformer including any items provided by sub-suppliers and all touch-ups and repairs made to the corrosion protection system during installation on site.

17.16.1 Minimum Requirements

The basic corrosion protection requirements for large power transformers shall apply as follows;

(1) Transformer conservators and radiators shall be hot dip galvanised steel

(2) Transformer steel tanks shall be thermally sprayed zinc treated as an initial treatment

(3) On Load Tap Changers (OLTC), Buchholz relay, gas pressure relay, Pressure Relief Devices (PRD), oil level indicators and cooling fans shall be protected in accordance with an offshore environmental protection category regardless of the individual product specifications.

(4) All cooling fan inlets and outlets, PRD vents shall be protected from wildlife intrusion with anti-bird mesh guards constructed of stainless-steel grade 316 or 316L.

The top finishing colour coat for transformers, radiators, conservator tanks and pipework shall be RAL 7033 (cement grey) unless otherwise detailed in the equipment specific specification. Where repairs or repainting of existing equipment is being performed the colour shall match the existing RAL 6020 (chrome green) where applicable.

17.16.1.1 Hot Dip Galvanised Steel

The following subsections detail are the minimum requirements of the painting and corrosion protection systems on transformers consisting off or Hot Dip Galvanised Steel and Thermally Sprayed Zinc-Coated Steel surfaces: Hot Dip Galvanised Steel

Hot dip galvanising of steel shall be fully compliant with the requirements of XDS-GFS-18.

The paint system for hot-dip-galvanised steel surfaces shall meet or exceed the requirements of Paint System G5.05 per Table D.1 of ISO 12944-5 (2019) (Corrosion Protection of Steel Structures), to provide high durability (above 20 years) coating with category C5-VH corrosion protection, suited to environments with high condensation, pollution and salinity as per ISO 12944-2.

The process for painting hot-dip galvanised steel shall be as detailed below:

Table 20 Painting process for hot-dipped galvanised steel

Process	Materials	Minimum Requirements	Minimum Value
Clean	Appropriate solvents or other cleaning agents	A grease / oil free substrate	-
Sweep blast	Aluminium oxide or another inert abrasive medium	A light texture with no more than 3 % of the zinc on the zinc layer removed by the process	SA 2.5
Priming	As per Paint System G5.05of ISO 12944	As per Paint System G5.05of ISO 12944	80 µm
Undercoating	As per Paint System G5.05of ISO 12944-5	As per Paint System G5.05of ISO 12944-5	160 µm (2 x 80 µm)
Finish coating	As per Paint System G5.05of ISO 12944-5	As per Paint System G5.05of ISO 12944-5	80 µm
Minimum Total Dry Film thickness			320 microns

17.16.1.2 Thermally Sprayed Zinc Coated Steel

The minimum thickness of the zinc coat shall be 150 µm.

The paint system for thermally sprayed metal surfaces shall meet or exceed the requirements of Paint System TSM 5.02 as per Table E.1 of ISO 12944-5 (2019) (Corrosion Protection of Steel Structures), to provide high durability (above 20 years) coating with category C5-VH corrosion protection, suited to environments with high condensation, pollution and salinity as per ISO 12944-2.

The process for thermally sprayed zinc coating and application of the required painting system shall be as detailed below:

Table 21 Painting process for zinc coated steel

Process	Materials	Minimum Requirements	Minimum Value
Process	**Materials**	**Minimum Requirements**	**Minimum value**
Metal spraying to ISO 2063	Zinc	150 µm	
Priming coating	As per Paint System TSM 5.02of ISO 12944-5	As per Paint System TSM 5.02of ISO 12944-5	80 µm
Stripe coat	As per Paint System TSM 5.02 of ISO 12944-5	As per Paint System TSM 5.02 of ISO 12944-5	Per paint application guidelines
Minimum total dry film thickness			320 microns

All edges, weld seams, flanges and other crucial areas shall be given an additional stripe coat with the same material as the primer.

In addition, the Customer may provide a separately priced option for any additional features or surface treatments which would contribute further to the long-term corrosion resistance of the equipment.

17.16.1.3 Corrosion Protection of Individual Items

The minimum requirements acceptable to the EirGrid for individual items shall be as follows:

a) Hot-Rolled Steel (Main Tank):

   i. Grit blasting to Sa 2.5 as defined by ISO 8501-1and BS 7079: 2009 (supported by ISO 12944).

ii. Painting As per 16.16.1.2 above ‘Thermally Sprayed Zinc Coated Steel’.

b) Conservator Tank:

i. Hot-dip galvanising, in accordance with XDS-GFS-18-001 and painting as per above ‘

ii. As per ‘Hot Dip Galvanised Steel’

c) Radiators, Mechanism Boxes, Marshalling Cabinets, Fasteners larger than 1 2mm Diameter and pipes:

i. Hot-dip galvanising, in accordance with XDS-GFS-18-001.

ii. As per ‘Hot Dip Galvanised Steel’

d) Smaller Fasteners, Cable Clips:

Non-ferrous materials or stainless steel to be used otherwise use of appropriately plated components to be used.

e) Inside of Tank:

Painting of the inside of the tank, oil pipes etc., with an approved oil resisting coating.

f) Roof/Cover of Tank:

In addition to the requirements of point (a) above the roof/cover of the tank shall be painted with non-slip paint, i.e. apply nonslip aggregate to an application of undercoat.

g) Nuts and Bolts:

All nuts, bolts and washers shall be stainless steel with grade A4 as per ISO 3506-1 (AISI 316) or better. Where they are in contact with aluminium, they shall be galvanised type and shall have grease applied (e.g. OLTC) to help prevent galvanic corrosion. All nuts, bolts and/or washers holding the OLTC in place shall be galvanised type and shall have grease applied. They shall all be manufactured in one factory.

h) OLTC Cover:

The corrosion protection system applied to the OLTC cover shall meet the requirements of ISO 20340 - Paints and varnishes, Performance requirements for protective paint systems for offshore and related structures.

All external surfaces shall be primed and finished in grey colour RAL 7033. The standard applicable to seals and gaskets shall be subject to approval of EIRGRID.

All necessary precautions shall be taken to prevent the aggressive ingress of moisture between flange plates, around gaskets and O-rings, at insulator/flange interfaces, etc. Tactile 506 type grease or equivalent shall be used if required. This shall apply to all devices provided by sub-suppliers e.g. thermostats, Buchholz relay.

The Customer shall protect all exposed points in their equipment at which aluminium or aluminium-alloy parts are in contact with or in close proximity to other metals and shall ensure that air and moisture are excluded from such situations.

If there are aluminium or aluminium alloy parts used such parts shall be anodised with painted or equivalent finish.

17.16.2 Testing of the Painting and Corrosion Protection System

The painting and corrosion protection system shall be type tested as per ISO 12944-6.

In addition, the following type and routine tests shall be carried out where they are not covered by ISO 12944-6:

a) The required tests of appearance on the painting and corrosion protection system for hot dip galvanised steel and thermally sprayed zinc coated steel are detailed below and shall be carried out as part of type and routine tests:

Table 22 Type and Route Tests Hot Dip Galvanised Steel

Test Method	Gloss	Colour	General Appearance
ISO 2813	80 +/- 10 Units @ 60˚		
ISO 11664		ΔE CIELAB of not more than 1.5 under D65 light source from the master chip agreed with EIRGRID	
Viewed in clear north light with the unaided eye at a distance of 2m.			The coating shall be of uniform appearance, with no inclusions, voids, or other blemishes, which mar the surface.

b) The required type and routine tests of performance characteristics on the painting and corrosion protection system for hot dip galvanised steel and thermally sprayed zinc coated steel shall be as detailed below:

Table 23 Type and Routine Tests Thermally Sprayed Zinc Steel Painting

Type Tests				
TYPE	**TEST METHOD**	**REQUIREMENTS**		
480 Hour Salt Spray	ISO 9227	Maximum Adhesion Loss at Scribe	Blistering Remote From scribe	Other Defects
		2mm	None	None
480 Hour Humidity	ASTM D 2247	Blistering	Colour Change	Other Defects
		None	None	None
Solvent Resistance Rub Test	ASTM D 4752	Corrosion	Blistering	Other Defects
		None	None	None
1,000 Hour UVA Artificial Weathering	ISO 4892-3	Maximum Colour Change	Maximum Loss of Gloss@ 60˚	Other Defects
		ΔE = < 2.6	< 25 %	None

Table 24 Painting and Corrosion Routine Tests

Routine Tests		
Test	Method	Requirements
Initial adhesion test (crosscut test)	ISO 16276-2 & ISO 2409	Classification 0 or 1
Delamination test (scribe test)	ISO 16276-2	Level 1
Cross hatch test	ASTM D 3359	Less than 5 % surface removed (classification 4 or better)
High build adhesion test (x-cut test)	ISO 16276-2 & ISO 2409	Level 1
Hardness Test	ASTM D 3363	No break of the topcoat up to and including 5H
High build >250µm adhesion test (pull off test)	ISO 4624	No adhesion break to the substrate allowed
Direct Impact	ASTM D 2794	Failure at 56 inch / lb minimum

Appendices

Refer to the latest version of Technical Schedules XDS-GTS-37-001.