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Functional Specification
OSP Primary Electrical Systems

Revision History						
Revision	**Date**	**Description**	**Originator**	**Reviewer**	**Checker**	**Approver**
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1 ABBREVIATIONS

Abbreviation	Definition
AC	Alternating Current
CENELEC	Commission Européenne de Normalisation Électrique
DC	Direct Current
DGA	Dissolved Gas Analysis
DGPT	Detection of Gas, Pressure, Temperature
FME(C)A	Failure Mode Effect (Criticallity) Analysis
GIB	Gas Insulated Busduct
GIS	Gas Insulated Switchgear
HS&E	Health, Safety & Environment
EHV	Extra High voltage (400kV or 220 kV in this document)
HV	High Voltage (For offshore platform typically 66 kV)
IEC	International Electrotechnical Committee
LCC	Local Control Cubicle
LOTO	Lock Out – Tag Out
LV	Low Voltage
MCB	Miniature Circuit Breaker
MPT	Main Power Transformer
NCC	National Control Centre
OEM	Original Equipment Manufacturer
OLTC	On Load Tap Changer
ONAN	Oil Natural Air Natural
ONAF	Oil Natural Air Forced
OSP	Offshore Substation Platform
OSS	Offshore Substation
PCB	Polychlorinated biphenyl
PD	Partial Discharges
SCADA	Supervisory, Control & Data Acquisition
SF6	Sulphur Hexafluoride
TSO	Transmission System Operator

2 SCOPE

This Functional Specification is applicable for use in offshore wind transmission links delivered by the Customer as Contestable Works, to be owned and operated by EirGrid.

This document is a supporting specification to OFS-OSP-130 OSP General Specification and shall be read in conjunction with that document and all associated EirGrid specifications.

This document provides general requirements for the design and construction of the Offshore Primary Electrical Systems which are installed on the Offshore Substation Platform (OSP). This primary plant covered in this document is as follows:

1. 220kV or 400kV Switchgear (Export)
2. Main Power Transformer (typically with 220kV).
3. Auxiliary Transformers
4. Earthing/Grounding Transformer
5. Earthing/Lightning Systems
6. Shunt Reactors (if applicable)
7. Platform EHV cabling

The Customer Array System Switchgear and associated control systems are not covered by this specification. They are the responsibility of the Customer.

This specification should be read in association with the project specific contestable works pack and project documentation and all other relevant functional specifications as issued by EirGrid.

The operational / ownership boundaries and configuration of the substation are not considered part of this specification but will be detailed in the EirGrid project specific Single Line Diagram and Interface Schedules as part of the Grid Connection Agreement.

For the purpose of this specification the term Customer shall refer to those party (Offshore Wind Developers, Independent Power Producers, Demand Customers, or other developers) responsible for the design and build of assets for connection to the Irish transmission system.

2.1 INTERNATIONAL AND IRISH STANDARDS CODES AND INDUSTRY PRACTICES

The standards set out in this specification define the minimum required and shall be without prejudice to any higher standard and codes of practice.

It is the responsibility of the Customer to ensure compliance with individual standards and additional applicable standards, including any future revisions.

2.2 ELECTRICAL STANDARDS

Table 1 Governing Standards & References

Document Number	Document Title
EN-IEC 62271-1	High-voltage switchgear and controlgear - Part 1: Common specifications for alternating current switchgear and controlgear
EN-IEC 62271-100	High-voltage switchgear and controlgear - Part 100: Alternating-current circuit-breakers
EN-IEC 62271-102	High-voltage switchgear and controlgear - Part 102: Alternating current disconnectors and earthing switches
EN-IEC 62271-110	High-voltage switchgear and controlgear - Part 110: Inductive load switching
EN-IEC 62271-200	High-voltage switchgear and controlgear - Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV
EN-IEC 62271-203	High-voltage switchgear and controlgear - Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV
EN-IEC 62271-209	High-voltage switchgear and controlgear - 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
EN-IEC 61869-1	Instrument transformers. Part 1: General requirements
EN-IEC 61869-2	Instrument transformers. Part 2: Additional requirements for current transformers
EN-IEC 61869-3	Instrument transformers. Part 3: Additional requirements for inductive voltage transformers
EN-IEC 61869-5	Instrument transformers. Part 5: Additional requirements for capacitive voltage transformers
EN-IEC 60076	Power Transformers. All Parts Apply
EN-IEC 60599	Mineral oil-filled electrical equipment in service - Guidance on the interpretation of dissolved and free gases analysis
EN-IEC 60296	Fluids for electrotechnical applications - Mineral insulating oils for electrical equipment
EN-IEC 60567	Oil-filled electrical equipment - Sampling of gases and analysis of free and dissolved gases - Guidance
EN-IEC 61099	Insulating liquids - Specifications for unused synthetic organic esters for electrical purposes
EN-IEC 60840	Power cables with extruded insulation and their accessories for rated voltages above 30 kV (Um= 36 kV) up to 150 kV (Um = 170 kV) - Test methods and requirements
EN 62067	Power cables with extruded insulation and their accessories for rated voltages above 150 kV (Um = 170 kV) up to 500 kV (Um = 550 kV) - Test methods and requirements
CENELEC-EN 50052	High-voltage switchgear and controlgear – Gas-filled cast aluminium alloy enclosures
CENELEC-EN 50068	High-Voltage Switchgear and controlgear - Gas-filled wrought steel enclosures
CENELEC-EN 50069	High Voltage Switchgear and controlgear - Gas filled welded composite enclosures of cast and wrought aluminium alloys
CENELEC-EN 50089	Cast Resin Partitions for Metal Enclosed Gas-Filled High Voltage Switchgear and controlgear

Document Number	Document Title
DNV-RP-N101	Risk management in marine and subsea operations
DNVGL-OS-D201	Electrical Installations
DNVGL-ST-0145	Offshore substations (October 2020 edition)

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

In case of conflict between this specification and any of the listed standards, this specification shall take precedence.

3 OFFSHORE SUBSTATION PRIMARY ELECTRICAL SYSTEMS AND EQUIPMENT

3.1 GENERAL FUNCTIONAL REQUIREMENTS

The primary electrical system shall comply with the DNV-ST-0145 standard.

The Customer shall consider the results of related mechanical studies (vibrational, lifting, skidding, tidal, mechanical impacts during transportation and installation) to confirm that all selected electrical equipment is suitable for the application in the offshore substation.

The Customer shall use results of the related electrical studies, including but not limited to load flow, short circuit, ampacity, insulation coordination, and transient/temporary overvoltage studies, to appropriately determine equipment rating, when also considering the network parameters. More details on studies can be found in OFS-OSP-130 and OFS-GEN-005.

All equipment shall be in new condition.

All offshore power equipment shall be properly tested and inspected during manufacturing, prior to transportation, storage (if applicable), and following installation as part of harbour and site acceptance testing, per requirements of EN-IEC standards as described in the following sections below. Further details on the testing and inspections to be performed are given in OFS-OSP-130.

The offshore substation shall not contain any open and air insulated High Voltage conductors. All High Voltage platform connections shall be made by screened insulated cable or gas insulated busducts. Alternative busduct designs (like air insulated bus-ducts) shall only be permitted with agreement by EirGrid.

Equipment shall be designed to be maintained in places with minimum disassembly of surrounding equipment and minimize use of temporary scaffolding and handling equipment.

Permanent platforms shall be provided where equipment inspections and small maintenance are required. In case this is not possible/sensible (e.g., at the top side of power transformers), anti-fall lines/harnesses shall be considered. In such cases appropriate attachment points or railings for the anti-fall lines/harnesses shall be provided.

Equipment arrangements, pipe routings and cable tray locations shall be designed for maximum equipment accessibility and to allow the following types of access:

- Space shall be provided to allow easy access and clearance of staff to all equipment and instrumentation, which may require maintenance.
- The arrangement shall be such, that all indicators, gauges etc. are in direct line of sight from the substation floor or permanent platforms
- Space shall be provided to allow unobstructed access for maintenance tools and equipment required for maintenance on permanently installed equipment.
- An allowance shall be provided for applicable condition monitoring technologies and equipment such as, but not limited to vibration analysis, oil analysis, infrared analysis, transducers and electrical measurements (e.g. motor circuit analysis, PD-measurements and ultrasound measurements) and gas quality measurements.
- In order to allow on-site power frequency / high voltage testing ample space shall be available to install and connect a separate high voltage source
- Space shall be provided to motor-operated equipment areas for work carts.
- Ample space shall be provided to allow removal and laydown of any equipment that cannot be maintained in place or may require disassembly or replacement (e.g., high voltage circuit-breaker assemblies).

Lifting eyes shall be provided on equipment to facilitate installation and removal for maintenance. Lifting eyes shall be designed with appropriate safety factors for offshore lifting.

Beams and trolleys shall be provided where necessary for maintenance, including removal, of all major pieces of equipment. The design shall provide for the use of lifting equipment to disassemble and reassemble heavy components:

- All equipment, when feasible, should be designed to be maintained and removed with portable lifting equipment. When not feasible, a crane facility of appropriate dimensions and capacity to lift heaviest single piece shall be incorporated in the GIS room. Capacity ratings shall be marked per EU-OHSA / Irish HSA requirements.
- For indoor equipment, portable lifting equipment may be used only to serve multiple plant equipment. All beams, trolleys and lifting equipment shall be marked with capacity ratings per EU-OHSA / Irish HS requirements. Beam trolley arrangements can be provided with common hoists, where appropriate.

Techniques for minimizing corrosion of structures and equipment potentially exposed to chemically or environmentally corrosive atmospheres shall be incorporated into the equipment design. Removable panels with lifting eyes on enclosures shall be provided where required.

Special attention shall be given to providing appropriate enclosures, curbs, drip guards and collection systems for fugitive water, hose spray water, chemicals and oils, if applicable.

General purpose single and three phase electrical outlets and outlets suitable for welding machines to support maintenance activities shall be provided, see OFS-OSP-136 for additional information.

Customer shall coordinate with the offshore substation topside structural contractor regarding

handling (dimensions, weight, etc.) and thus ensuring that requirements for the topside design and accessibility/maintainability/reparability strategy are met.

Equipment removal paths shall be shown on drawings and these paths shall be maintained clear of obstructions and interferences. 3D studies of OSP access paths shall also validate the above.

Access doors shall be provided in the rooms to accommodate maintenance of the electrical equipment. Door sizing shall consider all maintenance activities.

Standardisation of Components:

- Where feasible, similar equipment shall be provided by the same supplier to minimize spare parts inventories and to minimize the number of different suppliers' equipment that plant personnel must be capable of maintaining.
- Components shall be standardized to ensure that spares are:-
    - Optimized to reduce the number of component types and manufacturers
    - Readily available

3.2 INTERFACES BETWEEN EIRGRID AND CUSTOMER PRIMARY EQUIPMENT

3.2.1 REVENUE METERING

See OFS-GEN-016 EirGrid Functional Specification.

3.2.2 EHV AND HV SWITCHGEAR INTERFACES

It is expected that there will be signal exchanges between EHV (220kV) export GIS of EirGrid, main transformer of EirGrid and HV (inter-array) switchgear of Customer. These will include:

- Protection, tripping related signals, wiring
- Interlocking signals, wiring
- Transformer related alarms, trips.
- Other signals

Customer shall then submit the design proposal for the above interfaces to ensure safe operation of protection and control system to EirGrid for review.

Electrically wired interlocking will be acceptable. See OFS-GEN-016 (Protection Control Metering specification) for additional detail.

4 MAIN EARTHING/LIGHTNING DESIGN

Earthing and lightning protection will be based as per norms & standards for example

- IS EN 62305
- IS EN 50522

Earthing provisions (amount, rating, and location of earthing bars) shall be designed as per equipment supplier requirements and will be adequate to cover redundant earthing

connections.

Provision shall be made for connecting the GIS switchgear to the substation earthing system so that touch and step voltages are kept at safe levels.

The steps taken to minimise the Transient Enclosure Voltage (TEV) shall be described by the Customer.

Suitable Surge Voltage Limiters (SVLs) are to be installed if required by studies, including calculations for the expected sheath voltage.

If a number of compartments form one earthed unit, earth continuity shall be ensured across the flanged connections. An earthed unit shall be earthed at one position only.

Control units and mechanism boxes not earthed through connection to the main casing, shall have appropriate earthing terminals provided.

An earthing layout drawing, identifying all points of connection of the switchgear to the earth grid shall be provided with the detailed design.

During the installation of the earth system the Customer shall keep Earthing Quality Assurance records of the earthing system as it's laid including photographic evidence of joints and details of types of crimps and connections used.

Temporary earthing devices of adequate size and ratings shall be provided:

- Earthing points with a direct connection to the substation earthing shall be clearly marked.
- Earthing leads shall be provided with single-hand operated clamps and with fluid-resistant operation and maintenance instructions, cleared marked and bagged.

Additional information is contained in OFS-SSS-407 Earthing and Lightning Protection

5 Gas Insulated Switchgear (GIS)

The design of the EHV switchgear shall comply with DNV-ST-0145 in addition to standards referenced in this EirGrid specification.

See also OFS-SSS-413 Functional Specification 220 kV/ 400 kV Gas Insulated Switchgear (GIS).

6 Main Power Transformer (MPT)

The design of the main power transformers shall comply with DNV-ST-0145 as well as IEC 60076, in addition to standards referenced in this EirGrid specification.

6.1 Ratings, Design, and Construction

The main power transformers (MPT) shall be rated, designed, and manufactured based on requirements of:

- EN-IEC 60076: Power Transformers – all relevant parts

The Customer shall be responsible for all aspects of design, procurement, installation, testing

and commissioning of the MPT.

The rating of individual units shall be compatible with any limits imposed by:

- High voltage switchgear rating;
- Export cable rating;
- Medium voltage switchgear rating;
- Array cable rating.

MPT ratings shall be determined based on worst case operating scenario allowing for maximum MVA power flow and worst-case harmonic content. Adequate design margins shall also be applied.

In accordance with the wind farm installed capacity and the export system and array system switchgear configuration (e.g. single busbar, polygon, block), the transformer shall be either a two winding transformer or three winding transformer. The transformer materials selection, construction and operation shall comply with the current edition of IEC 60076. The voltage insulation levels, tolerances, operating voltages, lightning impulse and switching impulse levels, etc. shall be in accordance with IEC 60076.

The main power transformers with all additional accessories, the oil and the applied materials shall not contain any PCBs and the liquid insulation material shall not contain corrosive sulphur. The current-carrying capacity of the power transformers shall only be limited by the capacity of their cores and windings, and not by the ratings of other components such as cable terminations, tap changer, etc.

6.1.1 TRANSFORMER CORE AND WINDING

Transformer core and winding assemblies and all other internal parts shall be firmly located within the tank and capable of withstanding shocks to which they may be subject to during normal conditions of lifting, transport and installation.

6.1.2 INSULATING MATERIAL

The Customer shall discuss and agree with the Employer the type of insulating medium. The insulating medium shall be of high quality. The Customer is invited to consider the use of alternatives (see Section 3.3.4.3.3 of CIGRÉ 483, Guidelines for the Design and Construction of AC Offshore Substations for Wind Power Plants) to mineral oil which are considered to be environmentally responsible.

Synthetic ester fluid filled main transformers can also be used only if track record can be demonstrated from similar transformers and applications (including voltage levels, MVA capacity, design), and is of well proven design.

Mineral oil or synthetic ester fluid shall be compliant to relevant latest IEC standards. Type of oil or type of ester fluid shall be reviewed by EirGrid.

Paper shall comply with the requirements of IEC 60554-3 and IEC 60641.

6.1.3 On-Load Tap Changer

MPT shall be equipped with a high speed electrically driven OLTC (On Load Tap Changer) on the HV side for varying the effective transformation ratio. Tapping range and steps to be determined based on the project specific requirements and electrical system studies to cater for all possible credible operating scenarios. The OLTC shall comply with the requirements of IEC 60214 Series and shall be suitable for power flow in both directions. Only designs which have been type tested in accordance with these standards will be accepted.

The preferred OLTC manufacturer is Reinhausen (MR).

It shall be possible to control and monitor OLTC remotely from SCADA.

The OLTC shall have the capability to select the appropriate tap under any load, as well as receive and execute signals from a remote control system. The Customer shall ensure a minimum number of 500.000 tap changer operations before replacement. A non-resettable counter shall be fitted to the driving mechanism of the tap changer to indicate the number of operations completed.

Component parts of the tap changing equipment shall be accessible for examination, adjustment, and repair.

Tap changers are preferably to be of the combined selector diverter switch type. It shall not be possible for the oil in the diverter switch or selector switch compartments to mix with the oil in the transformer main tank or any other compartment. Access for inspection, diverter switch maintenance and manual operation of the tap changer shall be from ground level or from a permanently fixed work platform.

6.1.4 Magnetic Circuit & Losses

The magnetic circuit arrangement shall minimise the no-load loss and no-load current. The Customer shall carry out an optimisation of the load and no-load losses based on parameters to be agreed with EirGrid. The load and no-load loss and currents shall be stated.

Tolerances on transformer data shall fulfil the requirements of EN-IEC 60076-1, clause 9. and also with (EU) No 548/2014 in particular Table I.7: Minimum Peak Efficiency Index requirements for liquid immersed large power transformers as per Tier 2 applicable from 1st July 2021 a Minimum Peak Efficiency Index of 99.77% is required

In accordance with EN-IEC 60076 the measured total losses shall never exceed the guaranteed losses. If the measured losses exceed the guaranteed losses this will be considered as a non-conformance.

The short circuit losses of the transformer measured with the tap changer in the main position, the measured no-load losses and the losses in the cooler system will be used for loss evaluation. The evaluation criteria and data are given in the project specification. The transformer ratio for all positions of the tap changer shall not deviate more than 1/200 of the rated values.

If any unequal tap positions are defined, the measured values between two adjacent positions shall not deviate more than 1/7 of the rated values. In case of simultaneous ordering of identical transformers and in the case of a repeated order of identical transformers the variations between transformers in the transformation ratio on any tap changer position, shall

not exceed 1/400. The variation between transformers of the short circuit impedance, at any position, shall not exceed 1/20 of the measured average.

The arrangement of the magnetic circuit, magnetic shields, flux control devices, etc., and their supporting frameworks and clamping structures, shall:

- Minimise mechanical vibration and its transmission to the tank;
- Ensure that any vibration is not detrimental to the apparatus either under test or in service.

The sheet quality and induction shall be selected such that there is no troublesome hum or excessive overtemperatures that could be damaging to the sheet insulation or to neighbouring oil and insulating materials. It shall have a fixed mechanical structure, scarf joints and an adequate number of cooling channels. The structure shall not be degraded as a result of the temperature fluctuations that can occur during operation.

6.1.5 WINDINGS, CONNECTIONS AND TERMINAL MARKINGS

Windings and connections shall be designed and manufactured to meet the maximum voltage, thermal and mechanical requirements for test, transportation and in-service conditions. Conductors shall be of high conductivity copper. Aluminium shall not be used for windings or connections. The connectors shall be touch safe.

The windings shall be enamel covered.

The windings and leads of all transformers shall be braced to withstand the shocks which may occur through handling and vibration during transport, switching and other transient service conditions including external short circuit.

6.1.6 JOINTS

Quality of possible joints shall be documented. Photographs of the joints shall be submitted to EirGrid.

6.1.7 COOLING

The power transformers shall be rated for continuous operation with the delivered cooling system. If the MPT(s) include any means of forced cooling, the cooling system shall have sufficient redundancy of pumps and fans etc. such that the failure of a single item shall not reduce the transformer rating.

If several modes of cooling are possible, the cooling system shall be capable of automatically selecting the appropriate operation among the different modes (e.g. ONAN, ONAF) according to the transformer temperature.

In case of mineral oil filled transformers, they shall have ONAN or ONAN/ONAF cooling methods. ONAF can be in two stages. Other cooling methods can be considered only if accepted by EirGrid.

Transformer radiators, fan grills, control boxes/cubicles and pipe-work shall be hot dipped galvanized and painted or stainless steel. They shall be capable of being dismantled and equipped with radiator valves that allow them to be used with an oil-filled transformer. The

radiators shall be able to provide 100% cooling also when one radiator panel is removed.

During transport the radiators must be fitted with tight-sealing blank flanges to prevent any dirt or moisture penetrating. Painting specification to be reviewed by EirGrid and be suitable for an offshore, marine, harsh environment.

Temperature rise limits shall be in accordance with IEC 60076-2.

It shall be possible to drain any section of pipework independently. Drain valves or plugs shall be provided as necessary to meet this requirement.

The Customer shall provide EirGrid with details of the proposed cooling system design for review.

6.1.8 TRANSFORMER TANK

Each transformer shall be enclosed in a suitably stiffened welded steel tank such that the transformer can be lifted and transported without permanent deformation or oil leakage. The construction shall employ weldable structural steel.

Safety clearances shall enable operation, inspection, cleaning, repairs, painting and normal maintenance work to be carried out.

Lifting lugs shall be provided, suitable for the weight of the transformer, including core and windings, fittings, and with the tank filled with oil. Each tank shall be provided with at least four jacking lugs, and where required, with lugs suitably positioned for transport and lifting. Haulage lugs shall also be provided to enable a cable to be used safely for haulage in any direction.

The transformer tank shall be capable of withstanding full vacuum when empty of oil and hydraulic pressure test with no leakage or oil ingress.

The tank and cover shall be designed in such a manner as to leave no external pockets in which water can lodge, no internal pockets in which oil can remain when draining the tank or in which air can be trapped when filling the tank, and to provide easy access to all external surfaces for painting.

Each tank cover shall be of adequate strength, must not distort when lifted and shall be provided with suitable flanges having sufficient and properly spaced bolts. Inspection openings shall be provided to give access to the internal connections of bushings, winding connections and earthing links. Each opening shall be correctly located and must be of ample size for the purpose for which it is intended. All inspection covers shall be provided with lifting handles.

It must be possible to remove any bushing without removing the tank cover.

Pockets shall be provided for a stem type thermometer and for the bulbs of temperature indicators where specified. These pockets shall be located in the position of maximum oil temperature and it must be possible to remove any bulb without lowering the oil level in the tank. Captive screwed caps shall be provided to prevent the ingress of water to the thermometer pockets when they are not in use.

A spring operated, self-sealing, valve type, pressure relief device of sufficient size shall be

fitted to the tank for the rapid release of over pressure that may be generated in the transformer. Discharge of oil shall be directed away from the transformer top cover and clear of any operating position and ducted to a position approximately 1m from ground level.

All joint faces shall be arranged to prevent the ingress of water or leakage of oil with a minimum of gasket surface exposed to the action of oil or air.

6.1.9 CONSERVATOR TANKS AND BREATHERS

Each transformer shall be provided with an overhead conservator tank formed of substantial steel plates and arranged above the highest point of the oil circulating system. Connections into the main tank shall be at the highest point to prevent the trapping of air or gas under the main tank cover.

The capacity of each conservator tank shall be adequate for the expansion and contraction of oil in the whole system under the specified operating conditions. Conservator tanks shall also be provided with a cleaning door, filling cap, drain-valve with captive cap and an oil level indicator with minimum and maximum levels indicated. The normal level shall be indicated and the minimum and maximum levels shall also be correlated with oil temperature markings. The temperature markings shall preferably be integral with the level indicating device.

The conservator shall have a rubber sealing bag and the lifetime of this shall be stated. An instrument/indicator that shows if the bag is defect or not, shall be included. The type of instrument/indicator shall be described in the tender.

The location of the conservator tank shall be so arranged that it does not obstruct the passage of high voltage conductors immediately above the transformer.

6.1.10 VALVES AND PLUGS

As a minimum requirement the Customer shall include valves and/or plugs including a future possibility to install monitoring devices, or similar at the following locations:

- Main tank;
- Conservator;
- Tap changer;
- Radiators;
- Valve for oil samples (no monitoring device required);
- Valves for connection of oil treatment equipment.

6.1.11 CONNECTIONS, CABLING, BUS DUCTS AND BUSHINGS

The connection to the transformer will be made by cables (cable termination), cable bus or bus-duct. Thus, the transformer shall be designed to have a link box which, by temporary opening the link, enables high voltage testing of the cables according to relevant standards. The link box shall be able to withstand the voltage stress applied during the cable EHV tests.

Transformers are to be terminated with outdoor type bushings which shall be complete with all necessary fittings and comply with the requirements of IEC 60137.

Reduced insulation levels for neutral bushings are not allowed. The Contractor shall provide silicone-housed bushings only, porcelain housing are not accepted.

All equipment shall withstand the tests specified in this document. Where there is a requirement, accommodation for current transformers shall be provided in the bushing turrets.

6.1.12 EARTHING

Two steel flag type terminals shall be located one on either side and near to the bottom of the transformer to facilitate connection to the substation earthing system. The contact area and pressure shall be designed to withstand the maximum prospective earth fault currents.

All tank attached cubicles, cooling fan motors, tap changer drive mechanism etc. shall be bonded to their supporting structures. Paint shall be removed to ensure a good electrical connection with any exposed surfaces and subsequently re-protected by means of a corrosion-protective paint or coating.

6.2 ENVIRONMENTAL CONDITIONS

6.2.1 GENERAL

Environmental conditions shall be described in the basis of design as per relevant standards and good industry practice.

See OFS-OSP-130 for further requirements regarding the design basis and substation containment philosophy.

6.2.2 COATING

All components that are supposed to be placed outdoors or exposed to outdoor conditions shall be protected against corrosion due to the aggressive sea climate / environment by means of coatings according to class CX or better (acc. to ISO 12944 1).

The coatings shall have a durability of the lifetime of the Offshore Substation or shall be suitable for offshore repair works.

Evidence of compliance to class CX e.g., by accelerated ageing, humidity and salt spray tests according to ISO or IEC test methods shall be demonstrated by the Customer.

6.2.3 LIQUID LEAKAGE

Liquid immersed transformers shall be installed in an area or space with provisions for complete containment and drainage of liquid leakage.

6.2.4 AUDIBLE NOISE

The transformer sound level shall meet the requirements and be measured according to the methodology presented in standard EN-IEC 60076-10. The maximum sound pressure level (LpA) shall be as per EU regulations and/or Irish legislation.

6.3 SHORT CIRCUIT CAPABILITY

The transformer shall be capable to withstand the forces due to the rated short circuit currents, as informed by the Customer’s network engineering studies.

Transformers, including all equipment and accessories shall be capable of withstanding

without damage the thermal and dynamic effects of short circuits of all types during all foreseeable operating conditions as specified in IEC 60076-5, and with the following parameters:

1. Thermal Ability – duration of current: 2.0s
2. Dynamic Ability - duration of current: 0.5 s
3. Dynamic Ability - number of tests: 9

Minimum short circuit levels are specified in OFS-SSS-400 (Section for Network Parameters). The calculated short circuit currents are the basis for evaluation of the thermal and dynamical short circuit resistance of the transformer and will be used for the design review.

The ability to withstand dynamic effects of short circuit shall be demonstrated either:

1. By test
    a. The Customer may submit evidence of at least one short circuit withstand test result of transformers of similar design (as defined by IEC60076-5 Annex B) which have undergone this test in the last 5 years. (Consideration will also be given, however, to tests outside the 5-year period)

    or

    b. The Customer may undertake tests to prove dynamic withstand capability.

    or
2. By calculation and design and manufacture considerations in accordance with EN 60076-5.

The Customer shall provide calculations to demonstrate the thermal ability as part of the O&M manual for each and every transformer.

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.

Short circuit calculations shall be compliant to the latest IEC 60909 standard.

6.4 MONITORING AND CONTROL

The Customer shall propose and agree with EirGrid a suitable condition monitoring system including optical fibres for winding temperature / hot-spot monitoring.

The transformer shall be supplied with an on-line continuous gas-in oil incipient fault monitor for example Camlin G9 TOTUS types or similar.

For each transformer, the following monitoring shall be provided:

- On-Load Tap-Changer monitoring
- One (1) DGA monitoring system
- Oil and winding temperature shall be supplied (optical fibres).

The transformers shall be provided with a system for continuous monitoring of top and bottom oil temperatures, high- and low voltage winding temperatures (including hottest spot) and oil level. Oil level shall be monitored both for main tank and for diverter switch tank. The temperature readings, oil levels, alarms and the DGA readings/alarms shall be available on

the local HMI and remotely at SCADA, and shall register the highest temperature reached..

The above systems shall communicate with SCADA for monitoring, alarming, controls.

All contacts and other parts which may require renewal, adjustment or inspection shall be readily accessible.

All hand operated electrical control switches shall be clearly labelled and inscribed, as applicable, to indicate the function of the apparatus with which they are associated.

6.4.1 OIL LEVEL INDICATORS

Each oil container such as a transformer conservator, etc. shall be fitted with an oil level gauge located such that it is clearly visible from normal access levels.

6.4.2 ON-LOAD TAP CHANGE EQUIPMENT CONTROL

All on-load tap change equipment shall be provided with facilities for local and remote electrical control. These facilities shall permit extension for independent automatic or group parallel automatic operation from the control source.

6.4.3 COOLING PLANT CONTROL

The temperature indicators shall control the operation of the cooling plant motors automatically when the associated cooler control switch is set for AUTOMATIC.

The coolers and their control arrangements shall be such that failure of one part of the cooling equipment will not result in the loss of more than 50% of the total forced cooling capacity.

Each motor circuit or, as applicable, group of fan motor circuits, shall be provided with back-up protection of the motor protection relays by suitably rated fuses or miniature circuit breakers (MCB) mounted in the marshalling kiosk or cubicle.

6.4.4 VIBRATION AND ACCELERATIONS

Shock recorders and acceleration and wave movement detectors as well as environment recorders (temperature, moisture, etc.) shall be included and attached to the power transformer for transportation and lifetime operation.

6.5 **PROTECTION DEVICES**

The transformers shall at least be equipped with the following protection devices

1. Gas relay (Buchholz) for main tank, mounted between two (2) valves. Buchholz relay equipped with redundant alarm and trip contacts (twin float type), not sensitive to vibrations, equipped with gas sample device and testing facility. The testing shall be possible without dismounting it. It must be possible to visually check the presence and volume of collected gas in the relay (alarm and trip contacts shall be provided);
2. OLTC protection relay (including sudden pressure relay), mounted between two (2) valves (alarm and trip contacts shall be provided);
3. Sudden pressure relay or pressure relief device for the main tank. Alarm and trip

contacts shall be provided;

4. Oil level indicators on main tank and conservator with contacts for minimum and maximum oil level with visual indication on temperature scale. Clearly readable from ground level. Alarm contacts shall be provided;
5. Leakage detection system of membrane failure (with alarm contacts)
6. Dehydrating breathers equipped with alarm contacts
7. Four (4) pressure relief valves for main tank with relays and oil guidance. Alarm and trip contacts shall be provided;
8. Pressure relief valve / device for OLTC compartment with contacts and oil guidance. Alarm and trip contacts shall be provided;
9. Winding and oil temperature indications / monitoring. Alarm and trip contacts shall be provided;

6.6 TESTING

MPT testing and inspection shall be in accordance with the following standards:

1. EN-IEC 60076 – all relevant parts
2. EN-IEC 60599: Mineral oil-filled electrical equipment in service - Guidance on the interpretation of dissolved and free gases analysis

Tests shall include the following:

1. Production test and Factory Acceptance Test (FAT): Production tests are performed by the manufacturer at the factory as part of the process of producing the MPT. A full list of FAT items shall be provided to and reviewed by EirGrid prior to the start of tests;
2. Tests following any storage and prior to secondary shipment: Following any storage, a set of field tests shall also be performed on the MPT to confirm condition prior to secondary shipment. A full list of test items in accordance with manufacturer's recommendations shall be provided to and reviewed by EirGrid prior to the start of tests; and
3. Harbour Acceptance Tests [HAT]: Following MPT installation and assembly, a set of harbour tests shall also be performed on the MPT per requirements of the above-mentioned EN-IEC standards. A full list of test items shall be provided to and reviewed by EirGrid prior to the start of tests.

TEST PLANS, PROCEDURES SHALL BE REVIEWED BY EIRGRID

6.7 OPERATION AND MAINTENANCE

6.7.1 ACCESS

The Contractor shall provide sufficient space around the transformer and bushings/terminals to allow any repair or replacement to be safely carried out by typical fitters. Further, the transformer shall have ladders, rails, etc. for the access of the transformer's cover and top.

The transformer shall include supports for harness (internationally used and well-recognised fall-protection system, e.g. Latchways ®) for works on the transformer's tank top, e.g. welded on the tank top. Additionally, the transformer shall have manholes for access to the active part for visual inspection, after transportation, and O&M on-site (if applicable).

All valves, cabinets and marshalling boxes need a tag number and shall be lockable with padlocks.

6.7.2 SPARES

The Customer shall include within their scope of supply all consumable spares, e.g. if applicable dehydrating device, necessary for the ongoing routine operation of the power transformer.

The Customer shall provide a list of spare parts and consumables expected to be used during a period of 5 years, without warranting the correctness of the underlying assumptions and calculations, stating whether each is included in the tendered price or required to be purchased. Recommendations shall be provided and take into account the expected maintenance and expected failures of components.

The Customer shall be responsible for supplying any spare parts that are required during the warranty period, without additional charge to EirGrid and with replacement of any parts drawn from stock.

As far as practicable, all spare parts shall be commercially available for the lifetime of the OSP.

The Customer shall recommend how to store all spare parts and consumables. This shall include recommendations for local climatic conditions to prevent component degradation (e.g. through corrosion).

6.7.3 TOOLS

Where applicable, the Customer shall supply any special tools, specialist equipment and/or test equipment required to perform the installation, commissioning and lifetime operation and maintenance of the main power transformer(s), such as:

1. Hand cranks for manual operation of the tap changer;
2. Test bushings.

An adequate number, including spares, of each tool or piece of equipment shall be supplied by the Customer. Such tools shall be stored on the OSP. The Customer shall provide a suitable storage facility on the OSP for this equipment.

6.8 **OTHER REQUIREMENTS**

MPT receiving inspection, installation, and commissioning shall be in accordance with manufacturer's requirements and quality control/assurance plan.

Interface signals, functionalities (controls, alarms, trips, monitoring) between transformer and other systems (SCADA, switchgear) shall be fully tested end-to-end.

6.9 DOCUMENTATION

The Customer shall provide EirGrid with necessary instructions for operating and maintaining the MPTs.

The following documents shall be produced and supplied as a minimum:

- As-built documents;
- Design documents (technical specifications and descriptions, interface specifications, Test specification documents, detailed drawings for all accessories);
- Circuit Diagram;
- Manufacturing record document (including all information relevant to the manufacture and testing of the main power transformer and all inspection and test plan (ITP) records up to and including FAT);
- Test plan;
- Test manual;
- Documentation of type tests in accordance with IEC 60076 (lightning impulse, switching impulse, temperature rise and sound level);
- Documentation of tests after delivery;
- Rating plate;
- Layout diagram;
- Dimensional drawing;
- Overview diagram of the monitoring and protection equipment;
- General diagram of the pipes and valves;
- Description of all installed components (pumps, fans, valves, sensors, etc.);
- Operation and maintenance documents (maintenance plan, maintenance manual, operation handbook);
- Instruction manuals for replacing and repair of components.
- Transport and preservation procedures (for replacement and repair);

7 AUXILIARY TRANSFORMERS

7.1 RATINGS, DESIGN AND CONSTRUCTION

The auxiliary transformer can be liquid-immersed or dry-type transformer.

Design, rating, manufacturing and testing shall be in accordance with EN-IEC 60076-1 , and EN-IEC 60076-7 for liquid-immersed transformers or with EN-IEC 60076-11 and EN-IEC 60076-12 for dry-type transformers.

To ensure 2 x 100% redundancy, kVA rating of each auxiliary transformer shall be selected so ensure that each auxiliary transformer can support full expected load of the auxiliary loads plus 20% spare capacity. .

ONAN cooling shall be used for oil-filled transformer. AN cooling shall be used for dry-type transformers.

Oil-filled transformers shall be of hermetically sealed type and shall include alarm, tripping for

oil and winding temperatures, tank overpressure, gas generation, oil level.

DGPT (Detection of Gas, Pressure, Temperature) type devices can be used.

All alarms, trip signals shall be sent to SCADA, SCS.

To increase reliability of primary circuits, the auxiliary transformers shall be separate units (not integrated with MPT or earthing transformers). Exceptions to the above are possible only in certain cases and if agreed with EirGrid.

The auxiliary transformers will have cable terminations, not bushings.

No-load (offline) tap changer to be provided. Minimum tap range is +/- 5% at tap steps of 2.5%.

Testing of the auxiliary transformers shall be done according to IEC standards.

Interface signals, functionalities (alarms, trips, monitoring) between transformer and other systems (SCADA, switchgear) shall be fully tested end-to-end.

Test plans, procedures shall be reviewed by EirGrid.

7.2 ENVIRONMENT OF AUXILIARY TRANSFORMER

7.2.1 COATING

All components that are supposed to be placed outdoors shall be protected against corrosion due to the aggressive sea climate / environment by means of coatings according to class C5M or better (acc. to ISO 12944 1). The coatings shall have a durability of the lifetime of the Offshore Substation or shall be suitable for offshore repair works.

Evidence of compliance to class C5M e.g., by accelerated ageing, humidity and salt spray tests according to ISO or IEC test methods shall be demonstrated by the Customer.

7.2.2 LIQUID LEAKAGE

Liquid immersed auxiliary transformers shall be installed in an area or space with provisions for complete containment and drainage of liquid leakage.

7.2.3 AUDIBLE NOISE

The transformer sound level shall meet the requirements and be measured according to the methodology presented in standard EN-IEC 60076-10. The maximum sound pressure level (LpA) shall be as per EU regulations and/or Irish legislation,.

7.3 LOSSES

Tolerances on transformer data shall fulfil the requirements of EN-IEC 60076-1, clause 9 and also with (EU) No 548/2014

8 EARTHING/GROUNDING TRANSFORMERS

Grounding Transformer application, ratings, and testing shall be in accordance with EN-IEC 60076-6: Power Transformers – Part 6: Reactors and other relevant parts of IEC 60076.

The earthing transformers can be either oil filled or dry type.

Combined auxiliary and earthing transformers are acceptable only if a single failure of associated auxiliary transformer will not lead to loss of primary circuits (as a result of loss of neutral earthing on HV circuit).

To increase reliability of the primary circuit and wind power plant availability, a separate earthing transformer shall be provided unless it is agreed otherwise with EirGrid.

The grounding transformers shall be equipped with screened and earthed cable terminations.

Please also refer to the above section for auxiliary transformers. Requirements for design, construction, testing of earthing transformers and auxiliary transformers are similar (with exception of tap changes) and shall be followed.

8.1 ENVIRONMENT OF EARTHING/GROUNDING TRANSFORMERS

8.1.1 COATING

All components that are supposed to be placed outdoors shall be protected against corrosion due to the aggressive sea climate / environment by means of coatings according to class C5M or better (acc. to ISO 12944 1). The coatings shall have a durability of the lifetime of the Offshore Substation or shall be suitable for offshore repair works.

Evidence of compliance to class CX e.g., by accelerated ageing, humidity and salt spray tests according to ISO or IEC test methods shall be demonstrated by the Customer.

8.1.2 LIQUID LEAKAGE

Liquid immersed grounding transformers shall be installed in an area or space with provisions for complete containment and drainage of liquid leakage.

9 PLATFORM CABLING

The platform primary and auxiliary cabling shall be as per in DNV-ST-0145, and shall be arranged to suit project requirements. The Customer shall submit cable designs, schedules and drawings to EirGrid for review. The following main principles shall apply:

- OEM recommendations and applicable standards for cable installations, bending radius shall be respected;
- Minimise any points of vulnerability, failures.
- Cable distances shall be minimised;
- Cable splicing on OSP cables shall be avoided;
- Segregation and separation between voltage levels, power and control cables shall be implemented
- Electro-magnetic (EM) interference from power cables shall be minimised so that

there is no EM impact on any control and instrument operation, measurements.

- Cable trays, ladders shall be bonded between each other and earthed.
- Cables that may be exposed to potential mechanical damages shall be mechanically protected (conduits, trays or armour).