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Functional Specification

110/220/400kV Offshore Cables

Revision History					
Rev	**Date**	**Description**	**Originator**	**Checker**	**Approvers**
R0	09/07/12	First Issue	ESBI	Paul Moran	Christy Kelleher
R1	19/11/2018	- Revision of International standards - Additional updates to align with recent developments in offshore.	Mott MacDonald	Paul Moran, Conor Farrell	Brendan Murray

1 SCOPE

This specification describes the requirements for 110 kV, 220 kV and 400 kV AC submarine cables which will be connected to the transmission system.

It covers the design, manufacture, testing and installation in Irish waters of 110kV, 220kV and 400kV (nominal voltage) AC submarine cables, together with all accessories needed for their proper and reliable operation.

It does not cover the requirements for;

- inter array cabling in an offshore wind development; or,
- any land cable that may be connected to the submarine cable beyond transition joints at the shore landing point.

Note that some sections of this specification for submarine cables are identical to the specification for land cables.

2 SYSTEM PARAMETERS

The cables and accessories supplied shall be installed on a 3-phase AC 50 Hz system. The system parameters shall be as specified in EirGrid's 110/220/400 kV Station General Requirements Functional Specification.

The submarine cables and accessories shall be designed for operation on the system specified and to comply with the requirements laid down by this Specification.

2.1 SERVICE CONDITIONS

2.1.1 INDOOR ENVIRONMENTAL CONDITIONS

Where the submarine cable system is installed in substation buildings less than 1,000 metres above sea level;

(a) The following air temperatures apply:

- Maximum ambient temperature 40ºC.
- Maximum daily average ambient temperature 30ºC.
- Annual average ambient temperature 20ºC.
- Minimum ambient temperature -5ºC.

(b) Equipment will be exposed to:

- High Humidity up to 95%.
- Occurrence of condensation in Switchgear Rooms
- Salt laden atmosphere

We consider that these values are suitable to develop the design of the system and we expect the Contractor to validate the installation conditions on a project by project basis.

2.1.2 OUTDOOR ENVIRONMENTAL CONDITIONS

Where the submarine cable system is installed outdoors in Ireland in locations less than 1,000 metres above sea level.

(a) Please refer to the latest version of BS IEC 60287-3-1 for installation property assumptions using the values defined for the, “United Kingdom” for air and soil properties.

(b) The following sea temperatures apply:

- Maximum Sea temperature 16°C
- Minimum Sea Temperature -5°C

(c) The submarine cable system will be exposed to:

- Salt laden atmosphere wind blown salt deposits occur throughout the year.
- Wind Driven rainfall average 1,000mm per annum.
- Rainfall Frequency once every two days average.
- Heavily polluted atmosphere.
- Solar Radiation 420-870W/m²
- High Humidity up to 95%.
- Maximum wind (gust) velocity 50m/s.

We consider that these values are suitable to develop the design of the system and we expect the Contractor to validate the installation conditions on a project by project basis as outlined further in the DTS section.

3 STANDARDS AND REFERENCES

All materials shall comply with and be manufactured and tested according to the current edition of the standards of the International Electrotechnical Commission in so far as they are applicable. Where no IEC standard has been issued to cover a particular subject, then a recognised national standard shall be applied.

The 110 kV, 220 kV and 400 kV cables and associated fibre optic cables, where required, shall be manufactured, installed and tested in accordance with:

Cigré	Electra No. 171 - Recommendations for mechanical tests on submarine ` cables
Cigré	Electra No. 189 - Recommendations for testing of long submarine cables w ith extruded insulation for system voltage 30 (36) to 150 (170) kV
Cigré	Technical Brochure No. 272 – Large cross sections and composite screens design
Cigré	Technical Brochure No. 279 – Maintenance for HV cables and accessories
Cigré	Electra No. 296 – Guide on repair of conductors and conductor-fitting systems
Cigré	Technical Brochure No. 303 – Revision of qualification procedures for HV and EHV AC extruded underground cable systems
Cigré	Technical Brochure No. 398 – Third-Party Damage to Underground and Submarine Cables
Cigré	Technical Brochure No. 415 – Test procedures for HV transition joints
Cigré	Technical Brochure No. 490 - Recommendations for testing of long AC submarine cables for extruded insulation for system voltage above 30 (36) to 500 (550) kV
Cigré	Technical Brochure No. 560 – Guideline to Maintaining the Integrity of XLPE Cable Accessories
Cigré	Technical Brochure No. 610 – Offshore Generation Cable Connections
Cigré	Technical Brochure No. 623 – Recommendations for mechanical testing of submarine cables
Cigré	Technical Brochure 669 – Mechanical forces in large conductor cross-section XLPE cables
Cigré	Technical Brochure No. 680 – Implementation of long AC HV and EHV cable systems
Cigré	Technical Brochure 728 – On-site Partial Discharge assessment of HV and EHV cable systems
IEEE	1120 - Guide for the Planning, Design, Installation, and Repair of Submarine Power Cable Systems
IEEE	Vol PAS – 102 - Ampacity of electrical power cables in vertical protective risers
IEC 60050	International Electrotechnical Vocabulary
IEC 60060	HV Test Techniques

IEC 60071	Insulation co-ordination
IEC 60228	Conductors of Insulated cables
IEC 60229	Tests on cable oversheaths which have a special protective function and are applied by extrusion
IEC 60287	Electric cables – Calculation of the current rating
IEC 60793	Optical fibres IEC 60811- Common test methods for insulating and sheathing materials of electric cables
IEC 60815	Guide for the selection of insulators in respect to polluted conditions
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
IEC 60825	Safety of laser products
IEC 60853	Calculation of the cyclic and emergency current rating of cables
IEC 60949	Calculation of thermally permissible short-circuit currents
IEC 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
IEC 61238	Compression and mechanical connectors for power cables for rated voltages up to 30 kV (Um = 36 kV) - Part 1: Test methods and requirements
IEC 62217	Polymeric insulators for indoor and outdoor use with a nominal voltage >1 0 00 V – General definitions, test methods and acceptance criteria
ENA-ER-C55/4	Insulated Sheath Power Cable Systems
IEC 60794-1-1	Optic Fibre Cables – Part 1 Generic Specification – General
IEC 60794-1-2	Optic Fibre Cables – Part 1-2: Generic Specification – Basic optical cable test procedures
DNV-OS-H101	Marine Operations, General
DNV-OS-H102	Marine Operations, Design and Fabrication
DNV-RP-F401	Electrical Power Cables in subsea
DNV-RP-J301	Submarine Cable installation shallow water
DNV-RP-E307	Dynamic positioning systems -operation
ITU-T G.652D	Characteristics of Single Mode Optical Fibre Cable
ITU-T G.655E	Characteristics of a non-zero dispersion-shifted single-mode optical fibre and cable
EN 187105	Single Mode Optical Cable (Duct/Direct Buried Installation)
ISO9001:2008	Quality management systems
ISO14001:2004	Environmental management systems -- Requirements with guidance for use

IMO MSC/Circ 645 Guideline for Vessels with Dynamic

IMO-regulation International Maritime Organization.

SOLAS International Convention for the Safety of Life at Sea

XDS-GFS-17-001	EirGrid Specification: Galvanised fabricated steelwork

XDS-GFS-18-001 EirGrid Specification: Station Hot Dip Galvanising of Iron and Steel Other Than Wire

EirGrid Onshore Cable Functional Specifications (General Requirements, Route Selection, Cable Materials, Cable Civil Works and Cable Installation) – 110/220/400kV

'The Safety, Health and Welfare at Work (General Application) Regulations' 2001 and 2005

The Safety, Health and Welfare at Work (Construction) Regulations' 2001, 2003 and 2006

'Code of Practice for Offshore Diving' The Safety, Health and Welfare at Work (Diving at Work) Regulations' 2008

In any conflict between the standards quoted and this Specification, this Specification shall take precedence.

4 DESIGN

4.1 CABLE

The required lifetime for the submarine cable system (which includes the fibre optic unit if applicable) shall be at least 40 years. Where the fibre optic cable is separate from the power cable, the fibre optic cable shall also have a design lifetime of at least 40 years.

The proposed submarine cable system shall be designed and installed to take account of planned power system loads, environmental constraints and site conditions.

The design and installation of the cable shall be in accordance with best international practice and shall adhere to the appropriate international codes and standards. The cable shall be designed with ease of installation in mind and the design shall facilitate its ongoing operation and maintenance.

A minimum of 5 years' experience in submarine cable and accessory supply and installation at the voltage level for the project is required.

4.1.1 POWER CORE CONDUCTOR

Cable cores shall comprise a copper or aluminium conductor and shall be longitudinally water blocked in accordance with CIGRE TB 490.

The opportunity to utilise variable conductor sizes for submarine cable circuits may be considered however such designs should be considered in the associated spares offering, required as part of this specification.

4.1.2 METALLIC SHEATH

The metal sheath shall be of lead construction. The metallic sheath should also be longitudinally waterblocked to the same specification as the conductor according to CIGRE TB 490. A foil laminate sheath is not acceptable. To meet the short circuit requirements of this Specification, copper screen wires may, if required, be used in addition to the cable metallic sheath.

4.1.3 FIBRE OPTICS

Each three-core submarine cable shall contain two (2) fibre optic cables with 24 optic fibres each. The fibre optic cables shall be of a single-mode design. Fibre optic cables shall be suitable for operation at the prescribed water depth, radially water blocked and filled with a hydrophobic compound. The fibre optic cables shall not include low resistance metallic strength members such as aluminium armour wires; the impact of induced voltages, induced currents should be considered in their design. The requirement for earthing of fibre optic cables at both ends and within joints should be clearly shown/ stated in the bonding diagram.

Should single core submarine cables be proposed, the fibre optic cable shall be attached to the power cable externally. At the offshore to onshore transition joint bay, the fibre optic cores will be spliced to a separate fibre optic cable which will run in a separate duct from the power cable on the land section. The fibre optic cable system design should consider the following:

- The fibres shall be uniquely colour coded to allow for identification by the installer and maintenance teams; fusion splices shall be used at all splice locations and splices shall be minimised;
- Connectors are not permitted for single mode fibres.
- A schedule shall be completed and agreed with the Employer before purchasing of the fibres. See schedule template in Appendix A to be completed by the IPP.
- Compatibility with the onshore component of the fibre circuits should be considered when selecting a design.

The design of the cable shall consider the transportation and handling requirements envisaged for the submarine cable systems installation process. This shall include an assessment of the handling and manipulation cycles and forces required to transport the cable from the manufacturing facilities, to its final operational position. This to include offloading, handling between barges, transportation and installation vessels and during installation.

4.1.4 POWER CORE SHEATH AND COMPOSITE DESIGN

The cable cores and fibre optics shall have an outer sheath of medium or high density polyethylene and be surrounded by a bedded and protected armour package suitable for the installation conditions prescribed. Measures shall be taken in the design to limit potentials between conductive elements in the cable design and the Contractor shall demonstrate through calculation that potentials are not detrimental to the integrity of the system. This includes scenarios where the continuity of metallic paths may have been interrupted due to poor handling.

The cable design shall incorporate filler and bedding materials which are non-biodegradable for the submarine cable service conditions outlined in this Specification. The relative position of the power cores and fibre optic cables should be controlled along the length of the cable; the use of yarn fillers, or equivalent materials that may allow migration under strain, to separate these components is not acceptable. The Contractor shall demonstrate how the position of the fibre will be monitored / maintained during manufacturing and installation.

4.1.5 ARMOUR

Protective armour wires shall be applied over bedding layers on all cable designs. The outer layer shall be composed of polypropylene yarn fixed to the underlying armour wires via a compound which is stable for the conditions outlined in this Specification.

4.1.6 MARKING

The marking requirements for the outer polypropylene yarn layer shall be agreed with EirGrid. Where multiple cables form the scope of a contract, each cable shall be marked in a uniquely identifiable way (e.g. different colour or number of identifying stripes).

4.2 SPECIAL TECHNICAL REQUIREMENTS

The following minimum requirements shall be satisfied: -

1) The metallic sheath of each cable is required to be able to carry the full fault current specified in the associated Technical Schedule and as communicated in the project offer letter.
2) A semi-conductive water barrier shall be provided to limit longitudinal migration of salt water under the metallic sheath of the submarine cable in the event of damage to the sheath. The water barrier shall be capable of preventing longitudinal salt water movement along the cable when subjected to a pressure head corresponding to the maximum installed water depth. The IPP shall prove that the water blocking material is capable of preventing longitudinal salt water movement in the cable when subjected to load cycling similar to that prescribed in IEC tests for land cables. The length of salt water migration which occurs under such tests shall be a maximum of 10 m.
3) A semi-conductive water barrier shall be provided to limit longitudinal migration of salt water along non-solid conductors of the submarine cable in the event of damage to the sheath. The water barrier shall be capable of preventing longitudinal salt water movement along the cable conductor when subjected to a pressure head corresponding to the maximum water depth. Water penetration tests in accordance with Cigré Technical Brochure 490 shall be carried out. The maximum length of salt water migration which occurs under such tests shall be a maximum of 10 m.
4) Single core cables may be single or double wire armoured using strength members that will limit losses, such as stainless steel or copper as appropriate for the installation conditions. Three core cable designs may be single or double wire armoured using galvanised steel. The armour shall be of proven corrosion resistant design. The IPP shall provide evidence for a lifetime of at least 40 years for the armour design proposed in submarine conditions similar to Irish waters, for review by EirGrid.

4.3 DISTRIBUTED TEMPERATURE SYSTEM (DTS)

A distributed temperature sensing system (DTS) shall be supplied with the submarine cable system with a 40 year design life. The detailed functionality of the DTS system is to be discussed and agreed with EirGrid. The following functional requirements should be treated as a minimum:

The DTS system shall be provided with a fully interactive graphical interface that can be accessed at the onshore substation or remotely by EirGrid. The system should identify all parameters set out in Table 1 and be capable of providing temperature plots of cable section lengths of less than 10m. The DTS system should be capable of raising alarms via the SCADA system given temperature thresholds that are discussed and agreed with EirGrid.

The Optical Measuring unit shall be designed to account for suitable sensitivity attributed to fibre, splice and connector losses. In addition, the sensitivity shall include a margin of 1 dB to account for future fibre splices and performance degradation over the design life.

Table 1: Minimal DTS parameters

Parameter	**Requirement**
Temperature accuracy	<±1°C
Temperature Resolution	<1°C
Spatial Resolution	<2 m
Sampling resolution	<2 m
No. of channels	Contractor to discuss and agree with EirGrid.
Sampling period	<15 s

The DTS system design shall include all communications infrastructure between optical sensing units, data storage locations and remote access locations and any other infrastructure necessary to implement a fully operational DTS system. The DTS system design should allow for the storage of up to 12 months of system data.

An additional fibre shall be provided in the cable (for example at the metallic screen layer of the power cable) to enable accurate conductor temperature measurements to be determined. A single-mode, double ended configured DTS system is preferred for increased accuracy.

DTS systems shall have the capability of providing Real Time Current Ratings that can be integrated with SCADA.

A thermal validation of the operational cable system is required using the DTS as part of the offshore cable commissioning process. This will form the baseline for the operational phase and will supersede the design rating studies. The DTS system will be designed to ensure that cables are operated in a safe and reliable manner, reducing operational and surveying costs were possible. The location of all subsea cable and transition joints should be identified on the DTS system via a calibration process applied after joint construction.

The testing requirements for the DTS system are provided in Section 8.

4.3.1 TRAINING AND OPERATION

4.3.1.1 Training

The IPP will provide a comprehensive training course to EirGrid's operational staff. The IPP will include operational support for a period of 2 years after commissioning of the system has been completed. The operational support does not include site attendance for further training; EirGrid will inform the IPP of further training requirements upon completion of the commissioning.

The IPP will provide a full and complete operation and maintenance manual. The maintenance manual should clearly state operations which are to be performed by EirGrid and any specialist tools or training that is required and include this in the training course as provided (stated above).

As an option, the IPP shall provide a full operation and maintenance contract to EirGrid for a support period of 5 years.

4.3.1.2 Software Updates

Software updates for a period of 5 years shall be included in the supply of the system.

4.4 TRANSITION JOINT – LAND/SEA

Where land/sea transition joints are proposed, they shall be provided in a specially constructed joint bay on, or adjacent to, the foreshore end of the route. The overall transition joint construction shall provide an anchor termination for the armour wires of the submarine cable.

The land/sea transition joints shall be designed and tested in accordance with Cigré Technical Brochure 490. Prefabricated joint designs are required. Joints shall be fitted with a metal casing which shall be completely watertight to the standard of the cable itself. Insulated joints must be supplied in all cases.

The conductor shall be suitable for jointing by compression connector, shear bolt or welding. All connectors shall be proven to IEC 61238-1 or other equivalent long-term testing regime to be agreed with EirGrid.

Land/sea transition joints will be backfilled following assembly. Joint supports shall be adequate to prevent water ingress arising from relative movement of the cable and joint components after backfilling of joint bays.

The earthing design for the subsea power cables and fibre optic cables at the transition joint bay should be clearly stated on the design drawing submission.

4.5 REPAIR JOINTS

Submarine repair joints which minimise repair complexity and repair time are required. Repair joints must be suitable for operation at the required water depths. Details of the proposed repair joints and emergency repair proposal are to be provided. Repair joints are to be designed and tested in accordance with Cigré Technical Brochure 490. Any special tooling requirements should be clearly stated. The estimated jointing time for the repair joints should be clearly stated. (i.e. the time interval measured from when the cable is fully hauled and fixed aboard a repair ship, to the time when the submarine cable is ready for offloading back into the sea, excluding weather delays.

4.6 FACTORY JOINTS

The cables shall be manufactured in one continuous length without factory joints if possible. If the length of the submarine cable is such that there is no alternative but to use planned factory joints, their use shall be minimised and they shall be designed and tested in accordance with Cigré Technical Brochure 490. The installed location and phase allocation of all factory joints shall be clearly recorded and conveyed to EirGrid prior to manufacture.

Unplanned factory joints are not permitted without the express permission of EirGrid and then only after a full route cause analysis and investigation with corrective actions has been undertaken and subsequently communicated to EirGrid for review.

4.7 CABLE TERMINATIONS

4.7.1 GENERAL

The submarine cable system supplier and installer shall liaise with the offshore substation contractor on all interface issues between the submarine cable, offshore platform, onshore and offshore substation. Terminations shall be designed and tested in accordance with Cigré Technical Brochure 490 and IEC standards.

4.7.2 TERMINATIONS ON OFFSHORE PLATFORM

This specification assumes that the submarine cable will be terminated on a fixed offshore platform incorporating an offshore substation. The submarine cable is to be installed on platforms with hang-offs for the armouring and J-tubes with bend restrictors as required. Typical terminations at the platforms are of the plug-in type for the GIS substations.

The design of the J-tubes is the responsibility of the substation contractor with input from the cable contractor and shall meet the requirements of the submarine cables regarding minimum internal diameter and minimum bending radius. The J-tube bow radius shall be designed to be large enough to keep the sidewall force within the cable supplier's limits when being pulled up onto the platform.

The J-tubes shall be made of a suitably strong material such as carbon steel and protected against long term corrosion by means of a suitable coating or by other protective means (e.g. cathodic protection or a combination of both). Once the submarine cable has been pulled up onto the platform, the bell mouth of the J-tube shall be protected as required both mechanically and against corrosion. Due consideration shall be given to the potentially limiting current rating of the cable in the J-tube section when computing the circuit current rating in Section 5 of this Specification.

The submarine cable shall be suitably and securely anchored to a fixed structure via a hang off arrangement in order to follow the designed route and to avoid any movement under short-circuit events. The submarine cable shall be properly clamped at the terminations. All bend restrictors shall be designed to provide a lifetime of 40 years for the marine conditions which apply at the J-tube positions. The IPP shall provide evidence for this using fatigue test results which replicate the actual site conditions at the J-tubes.

4.7.3 GAS INSULATED METAL ENCLOSED SWITCHGEAR TERMINATIONS

The IPP shall ensure that the cable accessory manufacturer liaises with the supplier of the GIS equipment. This is to ensure that the limits of supply are clearly identified as per IEC and that entry and mounting details for the cable termination equipment is agreed.

The design shall permit sheath testing of the cable at 10 kV DC when the cable outer polymeric sheath material is of an insulated design. Dry type GIS terminations are preferred.

4.7.4 OUTDOOR TERMINATIONS

Where outdoor terminations are used, the minimum creepage distance shall be 25 mm/ kV. When installed in areas where salt pollution occurs, the creepage distance shall be based on the IEC class corresponding to heavy pollution. No arcing horns are required.

Outdoor sealing ends shall be fitted with a copper stalk of adequate cross-section for the cable rating and polymeric insulators.

Stand-off insulators are required to be capable of withstanding 10 kV DC for cable with an insulated outer polymeric sheath design.

Where applicable, the IPP should propose the use of suitable condition monitoring systems on cable terminations.

EirGrid will not accept termination designs for which no long term testing or lifetime proving has been undertaken, due to the real risk of explosive failure.

4.8 HV SUBMARINE CABLES

EirGrid shall advise on a project specific basis as to the required voltage and power flow rating according to EirGrid's strategic offshore grid development.

The general drivers are as follows:

Offshore cable installations will be 220 kV or greater, unless:

- the length of the offshore section is less than 5km or,
- the onshore circuit from connection point to a 220 kV interface point (i.e. the existing 220 kV network) is greater than twice the length of the offshore cable section;

In situations where the use of 220 kV or greater cables is not automatic the use of 110 kV cables may be considered as part of a strategic study, taking into account the potential longer term development of offshore generation and the onshore network.

The proposed cable system shall be designed and installed to take account of planned power system loads, environmental constraints and site conditions. The design and installation of the cable shall be in accordance with best international practice and shall adhere to the appropriate international codes and standards. The cable shall be designed with ease of installation in mind and the design shall facilitate its ongoing operation and maintenance.

Cables shall be manufactured and installed in accordance with the technical standards and safety legislation outlined in Section 3.

4.8.1 J TUBES

The following criteria should be considered during the J tube design process:

- Cable properties such as weight, stiffness and maximum allowed pulling forces;
- Tube length;
- Tube diameter;
- Tube material with respect to solar radiation absorption.
- Location on platform with respect to solar exposure;
- Friction coefficients;
- Bending radii;
- Lubrication methods;
- Corrosion prevention;
- Scour protection;
- Clamping of the cable to avoid vibration and cable fatigue;

4.8.2 LANDFALL HDD

The transition between land and sea installation of the subsea cable should be achieved by suitable trenching or troughing or, if suitable, landfall HDD. The design of the landfall HDD should consider the installation, operational, maintenance and decommissioning requirements of the subsea cable system. In particular, the following should be considered:

- Sufficient distance between the transition joint bay and the landfall HDD duct to allow for repair to the subsea cable system;
- Duct length;
- Duct diameter;
- Duct wall thickness;
- Duct material;
- Internal smoothness of duct joints;
- Cable properties such as weight, stiffness and maximum allowed pulling forces;
- Friction coefficients;
- Bending radii;
- Lubrication methods;
- Corrosion prevention;
- Scour protection

4.8.3 SWITCHGEAR LOCATION

Switchgear equipment should be positioned in order to facilitate cable terminations. In particular, the following should be considered:

- Sufficient space allowed to winch the cable up through the J-tube and into the switch gear room;
- Sufficient room to complete cable termination and anchor the cable armour;
- Design should ensure that cable pull-in tensions are not exceeded;
- Maintenance

4.8.4 OFFSHORE JOINTS

No offshore repair joints shall be used during installation without the prior agreement of EirGrid. The number of factory offshore joints shall be minimised and the economic and construction risk benefits of the proposed solution clearly identified.

5 CURRENT RATINGS

The current ratings shall be calculated in accordance with the current edition of IEC Publication 60287 and 60853 (Calculation of the cyclic and emergency current rating of cables) parts 2 and 3. The recommendations of Cigré publication ("Large Conductors and Composite Screens", Cigré Technical Brochure No. 272 by WG B1.03, Electra, June 2005) in relation to the rating of cables with large conductors shall be taken into account in the current rating calculations.

The project specific loading profile will be provided by EirGrid in the offer letter.

The input Environmental design assumptions to be utilised for cable calculations are as stated in Section 2 of this specification.

For submarine cables near the land/sea transition joint, where single core cables converge, the IPP shall detail the special measures (e.g. use of controlled backfill material) which will be used to offset the derating effect of the converging cables.

The maximum current carrying capacity in the sea-bed, in the water, in trenches and troughs and landfall HDD, J-tubes, ambient air, and converging cores (if relevant) are all to be considered in the calculation of the maximum acceptable current rating for individual circuits.

The thermal rating shall be validated as outlined previously using the DTS as part of the offshore cable commissioning process.

5.1 OVERLOAD RATING

The overload ratings for the durations requested in the schedules shall be provided. The conductor temperatures reached during these overloads shall be stated.

The maximum allowable cyclic conductor temperature shall be confirmed by the cable manufacturer.

The maximum allowable one second short-circuit conductor temperature shall be confirmed by the cable manufacturer.

6 SHEATH BONDING/EARTHING AND PHASING

All necessary power core and fibre optic cable inter-sheath and sheath to earth bonding conductors shall be of insulated copper of adequate cross-section. Full details of the necessary accessories such as link boxes, SVLs, bonding leads etc. shall be provided.

Fibre optic terminations at both the Transition Joint Bay and Offshore substation will occur at a kiosk provided by others. All fibre optic cables shall be terminated and earthed at these interface points.

Link boxes at the transition joints will be suitable for underground installation in pits and will permit isolation of each phase from the associated phase on the adjoining cable section for testing purposes. All link boxes will be lockable, fully waterproof and suitable for outdoor installation in Ireland.

The link boxes situated on the offshore substation shall be a gantry mounted design that is suitable for operation and maintenance within an offshore environment. They shall allow for the earthing of all subsea cable power core screens.

The sheath bonding and earthing scheme, including bonding leads shall generally be in accordance with Engineering Recommendation ENA-ER-C.55.4 published by the UK Electricity Association.

The IPP shall submit the following to EirGrid for review:

- Full sheath bonding/earthing scheme including phasing at each joint and termination;
- Sheath standing voltage calculations for the cable route, if applicable;
- Bonding lead cross section drawing and technical schedule;
- Link Box Drawings and general arrangement (including distances from joint)

7 MANUFACTURING PROCESS

7.1 GENERAL

The process of product manufacture shall at all times ensure that sufficient and adequate quality checks are carried out to determine compliance of design and component material with established criteria.

7.2 HANDLING OF MANUFACTURING PROCESS DEVIATIONS

Deviations from these criteria or any occurrence of manufacturing process deviation shall be immediately notified to EirGrid. In the event that remedial action, repair or reworking may be appropriate such action shall only proceed with the prior approval of EirGrid. Any product which has been repaired, reworked or has been the subject of remedial action without prior approval may be liable to rejection notwithstanding the results of any tests prescribed by this Specification. Any consequent delay due to the provisions of this Clause shall be the sole responsibility of the IPP and shall not relieve the IPP of its obligations regarding adherence to the works programme.

8 TESTS

Records of all tests carried out as requested in this Specification shall be submitted to EirGrid for review.

All routine, sample and type tests prescribed by this Specification shall be carried out at the expense of the IPP to the satisfaction of EirGrid, who may elect to have representatives present at any of the tests specified, at a time and date to be mutually agreed.

8.1 PREQUALIFICATION TESTS

Prequalification tests will be carried out on cable in accordance with Cigré Technical Brochure 490. Where prequalification tests have not been undertaken for this material then EirGrid will decide on whether prequalification testing is required or not.

8.2 TYPE TESTS

Type tests shall be carried out in accordance with Cigré Technical Brochure 490. For the electrical tests, the cable length shall be fitted with one of each type of accessory, joint, sealing end, factory joint and repair joint to be supplied. The type test cable lengths should include similar Fibre optic cable and joints to that proposed within the project. Where type tests have not been undertaken for this material then EirGrid will decide on whether type testing is required or not.

In relation to outdoor terminations, the IPP shall submit accelerated aging test, or other aging test results, to EirGrid which demonstrate that the following lifecycle failure modes have been addressed.

- Water ingress into fluid filled termination housings resulting from ineffective gasket or rubber seals.

- Corrosion failure of the insulator metallic parts / support bolts using 5000-hour corrosion test e.g. EDF salt fog test or other suitable test.

UV or overall weathering degradation of the polymeric termination insulator material using a 5000-hour multiple stress test (e.g. IEC 62217 Annex B, EDF salt fog test, or other suitable test).

8.2.1 DTS

Type testing of the Fibre optics, cables and connectors shall be in accordance with IEC 60794-1, IEC 60874-1 and the applicable ITU optical fibre standard.

In addition, the DTS system shall be Type Tested utilising the following withstand and reliability tests:

1) Supply Variation Non-Maloperate Test
2) Voltage Dips, Interruptions and Slow Variations – Non-Maloperate Test
3) Electrical Fast Transient/Burst – Non-Maloperate Test
4) Ring Wave and Damped Oscillatory Wave – Non-Maloperate Test
5) Electrostatic Discharge – Non-Maloperate Test
6) Radiated Radio Frequency Electromagnetic Field – Non-Maloperate Test
7) Conducted Disturbances Induced by RF Fields – Non-Maloperate Test
8) Mains Frequency Voltage Test
9) Conducted and Radiated Emissions Test
10) Inrush Current Test
11) Unless otherwise stated, the pass criteria for the tests shall be for the system to automatically reboot and function correctly following each test.

8.3 ROUTINE AND SAMPLE TESTS

Routine and Sample tests shall be carried out on each cable power core and each accessory manufactured in accordance with Cigré Technical Brochure 490 and IEC 60267. In addition, a Time Domain Reflectometry (TDR) test on each coiled up finished factory length will be required as well as an Optical Time Domain Reflectometry (OTDR) test on all optical fibres within the finished factory length. The test results will form a baseline for reference during the delivery, after laying, commissioning and operational phases of the cable. The High Voltage test as set out in Cigré Technical Brochure 490 should be completed on each finished individual power core prior to and after the lay up / armouring processes.

8.4 SAMPLE TESTS

Sample tests will be carried out on cable in accordance with Cigré Technical Brochure 490.

8.5 AFTER LAYING TESTS

- After the submarine cables are laid and before the shore end jointing proceeds, all of the fibre optic cores shall be tested.
- If the cable design permits (i.e. if the outer sheath is insulating rather than semiconducting), a 10 kV DC Test for 1 minute between cable sheath and earth

shall be carried out by the IPP after installation and before jointing in accordance with IEC 60229.

- Electrical tests after installation in accordance with Cigré Technical Brochure 490 shall be carried out. This shall include a high voltage AC test using a resonant AC test system with PD monitoring.
- A zero and positive sequence measurement shall be carried out.
- A TDR test shall be done on each conductor.
- As laid resistance and reactance data shall be recorded.
    - A copy of all test certificates must be provided by the IPP to EirGrid.

8.5.1 DTS

Attenuation testing using OTDR from both directions on all fibres shall be performed after installation and splicing activities.

The total measured end-to-end signal losses shall be a minimum of 1dB lower than the maximum permitted losses acceptable for the project and as previously submitted by the IPP and agreed by the Employer as part of the IPP test plan submission.

The maximum loss at any point discontinuity shall be 0.1dB.

8.5.1.1 Site Acceptance Testing

The following tests shall be undertaken as a minimum:

1) Tests on the Optical-electrical processing unit:
2) Calibration of temperature measurement using a minimum of two temperatures
3) Temperature resolution test
4) Temperature accuracy test at maximum measurement range
5) Scan rate test
6) Sampling resolution test
7) Spatial resolution test
8) Test of on-screen alarm display

Tests on whole system:

9) System resume after loss of AC power

Tests on data communication:

10) Tests to confirm SCADA connection and data transfer
11) Tests to confirm remote access including fault diagnosis

9 QUALITY ASSURANCE

All materials and workmanship shall be of a suitable type and quality to ensure that the cable system as a whole will operate satisfactorily in accordance with the Specification.

Each manufacturer shall have an implemented Quality Assurance Program conforming to ISO 9001:2000 or similar standard and shall provide an outline of the manufacturing process and the process controls.

EirGrid may desire to send a representative to the factory during the manufacturing of any or all of the cable lengths involved. The Supplier should arrange to notify the Purchaser in good time regarding the manufacturing programme for the cables.

A minimum of 5 years' experience in cable and accessory supply at the voltage level for the project is required.

10 INFORMATION AND DRAWINGS

In addition to the cable information, project information and drawings required in the General Requirements, the following documentation specific to submarine cable projects shall be submitted by the IPP in accordance with a programme agreed with EirGrid:

Consents

- Foreshore licence and associated conditions
- Easements/wayleaves details and drawings
- Local authority and other agreements
- Statutory Constraints e.g. cSAC, NHA
- Work Restrictions

Cable Route Design

- Proposed submarine cable route including temporary lay down if proposed during installation
- Locations and design detail of any required crossings of existing services along the submarine cable route
- Proposed planned joint locations
- Proposed landfall investigations and preparations
- Proposed landfall design
- Connection arrangements with Transition Joint Bay
- Production and installation programme
- Outline project organisation chart
- Details of sub-contractor for near shore civil works

Material / Cable system design

- Submarine cable cross section drawing
- Submarine Cable technical schedule (as per format provided)
- Proof of capability of water blocking materials in main conductor and in sheath area of power cores and fibre optics to block salt water at maximum installation depth

- Details of evidence for 40 year minimum lifetime of submarine cable armour material
- Outdoor Termination; Details of accelerated tests to confirm that failure modes of weathering, water ingress and corrosion have been undertaken to provide a 40 year lifetime for service conditions in this Specification.
- Factory joint details (if used)
- Repair joint details
- Transition joint details
- J tube details
- Landfall HDD duct details (if used)
- Wet storage cable capping details
- Phase Spacing proposed for single core cable designs
- Spare materials proposed for near shore and deep water repairs
- Details of Distributed Temperature sensing system
- Full details of power and fibre optic cable sheath bonding earthing and phasing
- Corrosion management

Transportation

- Plan for mobilisation, loading and transport of the land and submarine cables
- Details of all planned and un-planned cable transfer operations (from manufacture to installation) highlighting cable condition monitoring provision – evidence that these operations have been incorporated into the testing programme
- Programme of transportation and temporary storage if applicable
- Capability of transportation and storage vessels

Installation

- Programme of Installation
- Outline Method statement for the installation and protection of the submarine cable. Details of proposed installation equipment and vessels to be included.
- Operational limitations applying to cable laying, pull-in and protection work due to weather and sea conditions
- Emergency submarine cable repair proposal
- Near shore civil works design
- Proposed controlled thermal backfill between landfall and transition joint (if used)
- Detailed installation quality plan to address all aspects of the cable installation and repair operations.

Testing

- Prequalification Test Results
- Manufacturing test programme
- Type test results
- Factory acceptance test results (Routine, Sample and Type tests)
- Programme of cable delivery
- Soil thermal resistivity test results (as appropriate)
- After laying sheath test results
- Fibre optic test results (OTDR etc.)
- Steelwork test results
- Records of all tests as per IEC standards
- Thermal validation test results

The project as-built documentation is expected to show the finalised installation conditions for all HV subsea cable circuits. All survey and installed positional information should be made available in a suitable format for inclusion on marine navigation charts.

All other information necessary for a full understanding and evaluation of the proposal shall be included. The project safety file shall be submitted to EirGrid on completion of the project in accordance with the Construction Regulations.

11 SPARES

A submarine cable repair plan shall be proposed for each of the following failure scenarios:

- Failure at or near termination or transition joint
- Failure in near shore area
- Failure in deep water
- Failure in landfall HDD

The quantity and types of spares required must be sufficient to carry out a repair for each of the above failure scenarios after successful hand over of the assets. The spares provided should include submarine cable, repair joints, transition joints and terminations as appropriate to the particular project. Comprehensive jointing and termination instructions provided for all proposed power core cable sizes and fibre optic cables. The spare cable provided shall be placed on a suitable galvanised steel drum, basket or turntable which shall be lagged or covered with suitable material to provide physical protection for the cables during shipment, storage, handling and in the case of cable spares, the required design life. This lagging shall also provide suitable protection against all climatic conditions prevailing on site. The ends of the cable shall be durably sealed before shipment with plumbed lead caps and with heat shrink protective covers to prevent ingress of moisture and shall be firmly and properly secured to the drum. The direction for rolling shall be indicated by an arrow. This is the opposite direction to that of cable pay off.

Spare cables shall be provided in a single length with no factory or repair joints.

The length of spare cable in particular is an important aspect which must be reviewed and approved by EirGrid on the basis of individual details and peculiarities of each submarine cable route.

Spare Accessories shall be supplied in strong wooden boxes, suitably protected against damage which may occur during shipment, handling or storage operations. All spare boxes/drums shall be clearly labelled detailing the project and content description. As far as is possible, complete accessories shall be packaged in individual boxes, including all mechanical parts, tapes etc.

Both the shelf life and expiry date of any degradable material provided as spares shall be clearly stated on a durable label on the packing box. These shall also be communicated to EirGrid. The IPP is responsible for the replacement of these materials and any costs associated with their replacement once they expire.

The long-term storage facilities for these spares, which are designed for indoor storage only, must be assessed and approved by EirGrid on the basis of access, security and weather protection offered.

One full set of special jointing tools shall be provided to EirGrid where non-standard accessories are used.

12 Submarine Cable Installation

12.1 General

The cables are to be installed in accordance with the requirements of the Irish Department of the Environment foreshore licence and the installation should follow the guidelines set out in the IEEE 1120 Standard (Guide for the Planning, Design, Installation, and Repair of Submarine Power Cable Systems). Any deviations from the original route or burial conditions due to circumstances not revealed by surveying or other unknowns should be agreed with the Department of the Environment.

12.2 Requirements

The IPP shall provide details of the proposed installation methods and detail proposals for mechanical protection of the cable. For a single core proposal, the IPP shall confirm if an additional spare core will be laid and what procedures and facilities will be put in place to energise such a spare core in the event of failure of another cable core.

The mechanical stresses on the cable during installation shall be kept within the cable manufacturer's specified limits. The IPP shall produce a cable laying plan detailing the pulling tension, lay angle and residual horizontal tension on the sea bed that is required for safe installation, post-lay burial and minimising the risk for free spans.

The submarine cable will be embedded in the sea bed to a minimum depth of 1 metre by a technique such as high pressure water jetting or ploughing. Greater burial depths may be required by EirGrid in areas where the risk of mechanical damage is greater such as in shipping lanes, or as required by the Foreshore licence. The effect of increased burial depth on cable rating shall be taken into account.

If it is not possible to bury the cable to the full depth requirements stated above, then the IPP shall provide details of additional measures to protect the submarine cable at such locations.

The IPP shall provide details of all near shore civil works required for the submarine cable installation.

The IPP shall submit a detailed installation Quality Plan to address all aspects of the cable installation and repair operations for assessment and approval by EirGrid.

Phase Separation

For single core cables, the IPP shall propose a phase spacing taking the following issues into account:

- Each phase of the cable circuit is to be buried in a separate trench in the seabed.
- It should be possible to repair any phase by raising it to the surface and lower it again without it having to cross one of the other cables.
- There should be no risk of damage to other phases during the jetting operations
- There should be no de-rating due to proximity to other cables.
- Ease of installation

As-built survey

The cable position and burial depth shall be accurately recorded and verified using the DTS system prior to asset hand over. The required as-built survey requirements shall be agreed with the IPP.

12.3 COMPLIANCE

Compliance with all relevant Irish Diving Regulations, Construction Laws and Health and Safety Legislation is required for the installation of the cable.

13 STEELWORK

The IPP shall submit a proposal for all cable termination steelwork support structures. The submission shall provide details of the all physical loadings exerted on the steelwork and designs confirming the capability of the steelwork to withstand the forces. As a minimum, the impact of thermo-mechanical forces exerted by the subsea cable shall be considered in the design. The steelwork support design will need to consider the requirements for both the installation and potential maintenance methodologies – coordination with the cable installation contractor is required. The impact of induced currents should be considered in the steelwork design as well as the requirements of installation and maintenance operations.

All steelwork shall be hot dip galvanised as per EirGrid specification XDS-GFS-18-00. The IPP shall supply their chosen galvaniser with as much information as required relating to the composition and nature of the base metal material used.

If it is necessary to bore vent or have drainage holes in articles, the IPP may do so only after the consent of EirGrid has been obtained.

The IPP shall ensure that internal stresses in the material brought about by such treatment as extensive cold working are relieved before submission for hot dipping.

The zinc of the hot dip galvanising bath shall contain not less than 98.5 % by mass of zinc according to ISO 752. No zinc impurities or additives which could have a deleterious effect on the durability effect of the zinc coating will be acceptable.

The galvanising coating shall be smooth, continuous, uniform and free from anything that is detrimental to the stated use of the coated article. It shall be free from acid spots, flux stains and shall not scale or blister, or be removable by normal handling or packing.

The thickness of the galvanising coating and the mass of the galvanising coating per square metre of the surface area shall comply with the minimum average values given in the table below, when tested in accordance with the requirements of this Specification.

The uniformity of the galvanising coating shall be such that the minimum individual thickness measurement on any test sample shall not be more than 7 microns (µm) below the minimum average figure specified in below for the chosen article:

Description Of Articles	**Minimum Zinc Mass Deposited (grams / metre²)**	**Minimum Average Coating Thickness In Microns (µm)**
Steel Items 5 mm thick and over	610	85
Steel Items between 2 mm and 5 mm thick	460	65
Steel Items under 2 mm thick	335	47
Threaded Steel Items	305	43
Iron Castings	610	85

13.1 HEAVY POLLUTION AREAS

Where the IPP proposes installing the cable in an area which could prove detrimental to the steelwork, they shall provide a factory duplex painting system to protect against corrosion due to the coastal area. The IPP shall submit the proposed paint treatment to EirGrid for review.

13.2 TESTS ON STEELWORK

The tests detailed in this Specification shall be carried out by the IPP to the satisfaction of EirGrid. Only on receipt and approval of the test certificate, may the consignment be installed.

EirGrid shall have the right to witness the tests and to inspect the parts of the Galvaniser's works during the work on the consignment.

The IPP shall give EirGrid at least 10 days advance notice of the date of testing.

The following tests shall be carried out on the selected samples.

- Visual Inspection
- Thickness of Coating
- Uniformity of Coating

Visual inspection of the consignment shall include the following elements:

- Smoothness
- No exposed spots, spikes, or anything detrimental to stated use of the articles or to workmen handling them.
- Stains
- No acid spots or flux/dross stains.
- Adhesion
- No blisters, peeling or flaking shall be accepted. The steelwork must be able to withstand normal handling without deterioration.

- Wet Storage
- Mitigation measures should be taken for storage/stacking of the materials to prevent white rust. Excessive white rust will cause the consignment to be rejected.
- Threaded Items
- The threads on the nuts should be cut oversize. This is to allow for the galvanising coating on the standard bolt threads.

Thickness measurements shall be determined by a magnetic instrument method as set down in ISO Standard 2178. The instrument used shall have the necessary degree of accuracy, range of probes and probe adapters to enable reliable readings to be obtained consistently.

Otherwise the IPP shall nominate a suitable instrument for the purpose of obtaining the measurements. Before commencement of the measurements the instrument shall be calibrated, preferably on an ungalvanised sample of the article under test.

The mass of coating shall be determined by a coating stripping procedure as set down in ISO Standard 1460. For shaped articles, details of the method of calculating the surface area shall be agreed between the IPP and EirGrid.