OFS-CAB-100-R3

Functional Specification

220 kV Submarine Cables

		Revision History				
Revision	**Date**	**Description**	**Originator**	**Reviewer**	**Checker**	**Approver**
R2	28-10-22	Issued for use after final industry feedback,	Daniele Giustini	Neil Cowap	Leon Notkevich	Louise O Flanagan
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1 SCOPE

This specification defines the objectives, guidelines, and requirement of 220 kV XLPE insulated submarine cable system, in the stages of cable system design, design qualification, manufacture, production, factory inspection, tests, transportation and installation, tests after installation, and decommissioning.

Operation and Maintenance requirements for the 220kV submarine cable system are described in the OFS-GEN-009 specification.

This specification is applicable to 220 kV AC submarine cable systems up to 200-meter water depths with fixed installation (static submarine cable system) including cables with integrated Fibre optic (FO) cable, together with all accessories, as defined in 6.9, and ancillary equipment needed for their proper and reliable operation.

It is not intended to cover the requirements for:

- Inter-array cable system
- Floating cable system
- Land cable that may be connected to the submarine cable beyond transition joints at the shore landing points.

2 ABBREVIATION LIST

List of Abbreviation is given in table below.

AC	Alternating current
ALS	Accidental Limit State
ASD	Allowable Stress Design (effectively the same as WSD)
CSA	Cross Section Area
CT	Current Transformer
DAC	Damped Alternating Current
DAS	Distributed Acoustic Sensing
DC	Direct current
DTS	Distributed Temperature Sensing
EPR	Ethylene Propylene Rubber
FAT	Factory Acceptance Test
FO	Fibre Optic
GIS	Gas Insulated Switchgear
ITP	Inspection and Test Planning

LWP	Longitudinal Water Penetration
LRFD	Load and Resistance Factor Design
OTDR	Optical Time Domain Reflectometer
PD	Partial Discharge
PMD	Polarization Mode Dispersion
PQ	Pre-qualification
RTTR	Real Time Thermal Rating
RWP	Radial Water Penetration
SAT	Site Acceptance Test
SC	Short Circuit
SCADA	Supervisory Control and Data Acquisition
SLTJ	Sea Land Transition Joint
TJB	Transition Joint Bay
TDR	Time Domain Reflectometry
TP	Transition Piece
TR-XLPE	(water) Tree Retardant XLPE
UV	Ultraviolet
VIV	Vortex-induced Vibration
VLF	Very Low Frequency
VPN	Virtual Private Network
WSD	Working Stress Design
WTG	Wind Turbine Generator
XLPE	Cross Linked Polyethylene

3 Governing Standards

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

The 220 kV cables and associated FO cables, where required, shall be manufactured, installed, and tested in accordance with standards and guidelines below. In any conflict between the standards quoted and this Specification, this Specification shall take precedence.

IEC 60228	Design and construction requirements for conductors of insulated cable
IEC 60229	Tests on cable over sheaths which have a special protective function and are applied by extrusion
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 60793	Optical fibres guidelines
IEC 60071	Insulation co-ordination
IEC 61936-1	Power installations exceeding 1 kV AC - Part 1: Common rules
IEC 60287	Calculation methods for steady state current ratings and losses
IEC62271-209	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
IEC 60853	Calculation methods for cyclic and emergency current rating of cables
IEC 60949	Calculation of thermally permissible short-circuit currents, taking into account non-adiabatic heating effects
IEC 61914	Cable cleats & short circuit protection calculations
IEC 61443	Short-circuit temperature limits of electric cables with rated voltages above 30 kV (Um = 36 kV)
IEC 61892-4	Guidance and requirements for the selection of electrical cables intended for fixed electrical systems in mobile and fixed offshore unit
IEC 62271-209	connection assembly of fluid-filled and extruded cables to gas-insulated metal-enclosed switchgear (GIS) for rated voltages above 52 kV

IEC 60332	Tests on electric and optical fibre cables under fire conditions
IEC 60793	Optical fibres
IEC 60794	Uniform generic requirements for the geometrical, transmission, material, mechanical, ageing (environmental exposure), climatic and electrical properties of optical fibre cables and cable elements, where appropriate
IEC 61386-24	Conduit systems for cable management - Part 24: Particular requirements - Conduit systems buried underground
IEC 60811	Common test methods for insulating sheathing materials of electric and optical fibre cables
IEC 60874-14	Connectors for optical fibres and cables
IEC 61300	Fibre optic interconnecting devices and passive components- basic test and measurement procedures
IEC 61757	Fibre optic sensors
IEC 62134	Fibre optic interconnecting devices and passive components- fibre optic closure
IEEE Vol PAS – 102	Ampacity of electrical power cables in vertical protective risers
IEEE 1120	Guide for the Planning, Design, Installation, and Repair of Submarine Power Cable Systems
ISO 9001	Quality management systems — Requirements
ISO 14001	Environmental management systems — Requirements with guidance for use
ISO 14005	Environmental management systems — Guidelines for a flexible approach to phased implementation
EN 10257-2	Zinc or Zinc Alloy coated non-alloy steel wire for armouring either power cables or telecommunication cables. Part 2: Submarine cables
EN 60529:1991	Degree of protection provided by the enclosures
Cigré	TB 303 – provides a guide of deal with the revision of qualification procedures of underground HV and EHV cable systems with possible changes in cables or accessories
Cigré	TB 490 – provides recommendations for testing of long AC submarine cables with extruded insulation for system voltage above 30 (36) to 500 (550) kV

Cigré	TB 623 – provides recommendations for mechanical testing of submarine cables
Cigré	TB 640 – A guide for rating calculations of insulated cables
Cigré	TB 669 – Mechanical forces in large cross section cable systems
Cigré	TB 756 – Thermal monitoring of cable circuits and grid operators' use of dynamic rating system
Cigré	TB 773 – Fault location on land and submarine links [AC & DC]
Cigré	TB 770 – Trenchless technologies
Cigré	TB 801 – Guidelines for safe work on cable systems under induced voltages or currents
Cigré	TB 841 – provides guide for after laying tests on AC and DC cable systems with new technologies
Cigré	TB 850 - Harmonised test for the measurement of residual methane in insulating materials
Cigré	TB 883 – Installation of Submarine Power Cables
Cigré	WG B1.70 – Recommendations for the use and testing of optical fibres in submarine cable systems (in progress- to be issued November 2021)
Cigré	TB 680 – Implementation of long AC HV and EHV cable systems
Cigré	TB 728 – On-site Partial Discharge assessment of HV and EHV cable systems
Cigré	TB 272 – Large cross sections and composite screens design
Cigré	TB 279 – Maintenance for HV cables and accessories
Cigré	TB 825 – Maintenance of HV cable systems
Cigré	Electra 296 – Guide on repair of conductors and conductor-fitting systems
Cigré	TB 398 – Third-Party Damage to Underground and Submarine Cables
Cigré	TB 815 – Update of service experience of HV underground and submarine cable systems
Cigré	TB 415 – Test procedures for HV transition joints
Cigré	TB 560 – Guideline to Maintaining the Integrity of XLPE Cable Accessories

Cigré	TB 610 – Offshore Generation Cable Connections
Carbon Trust CTC 835	Cable Burial Risk Assessment Methodology: Guidance for the Preparation of Cable Burial Depth of Lowering Specification (February 2015) and associated Application Guide for the specification of depth of lowering (17 December 2015)
DNV-RP-F401	Supplement to ISO 13 628-5 provides recommended practice for electrical cables in subsea applications
DNV-ST-0359	Subsea power cables for wind power plants
DNV-RP-0360	Subsea power cables in shallow water
DNV-RP-F109	On-bottom stability
DNV-RP-F105	Free spanning pipelines
DNV-RP-N101	Risk management in marine and subsea operations
DNV-RP-E307	Dynamic positioning systems -operation
DNVGL-ST-N001	Marine operations and marine warranty 2019/2020 (Please note that DNV-OS-H102 referenced in listed documents, is replaced by DNV-ST-N001)
ITU-T G.650	Definition and test methods for the relevant parameters of single-mode fibres
ITU-T G.652	Characteristics of a single-mode optical fibre cable
ITU-T G.654	Characteristics of a cut-off shifted single-mode optical fibre cable
ITU-T G.655	Characteristics of a non-zero dispersion-shifted single-mode optical fibre and cable
ITU-T G.657	Characteristics of a bending-loss insensitive single-mode optical fibre and cable
ITU-T G.972	Definition of terms relevant to optical fibre submarine cable systems
ITU-T G.976	Test methods applicable to optical fibre submarine cable systems
ITU-T L.12	Optical fibre splices
EIA/TIA-455-13	Visual and mechanical inspection of fibre optic components, devices, and assemblies
EIA/TIA-455-61	Measurement of fibre or cable attenuation using an OTDR
ENA EREC C55	Insulated sheath power cable systems

IMO MSC/Circ 645	Guidelines for vessels with dynamic positioning systems
SOLAS	International Convention for the Safety of Life at Sea
OSCR	The Offshore Installations (Offshore Safety Directive) (Safety Case etc.) Regulations
OFS-SSS-419	EirGrid Specification: Galvanised fabricated steelwork
OFS-SSS-420	EirGrid Specification: Station Hot Dip Galvanising of Iron and Steel Other Than Wire
Directive 2011/92/EU	Assessment of the effects of public and private projects on the environment
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	

4 General Requirements

The cable and its installation shall comply with this Specification unless any deviation/derogation which has been specifically requested by the Customer is accepted in writing by EirGrid.

Further information is outlined in EirGrid's Derogation Process OFS-GEN-024 (which will be based on XDS-GGD-00-001-R0 Guidance for Derogation Requests). Early engagement pre-construction with EirGrid should be sought for any proposed deviations.

4.1 Network 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 OFS-SSS-400 specification.

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

The cable system shall be designed to operate for nominal and short circuit levels as specified in the OFS-SSS-400 specification.

The minimum rating requirement of the cable is dependent on the Customer specific connection. The Customer shall calculate the current rating for their cable system based on relevant project characteristics and the requirements in this Specification. Selection of optimum cable sizes shall follow the requirements in Section 5.6 of this Specification.

4.2 SERVICE CONDITIONS

The proposed cable system shall be designed and installed to take account of environmental constraints and site conditions.

The cable system shall be capable of operating satisfactorily at the service conditions as per the Customer's project specific design basis.

The Customer shall validate the installation conditions on a project-by-project basis.

4.2.1 INDOOR ENVIRONMENTAL CONDITIONS (OFFSHORE SUBSTATION)

See general specifications document OFS-SSS-400.

4.2.2 OUTDOOR ENVIRONMENTAL CONDITIONS

See general specifications document OFS-SSS-400.

Site specific marine environmental conditions shall be investigated by the Customer before FEED commences.

4.3 SUPPLIER EXPERIENCE REQUIREMENT

4.3.1 GENERAL REQUIREMENT

It is preferred to have one supplier with cable and accessories manufacturing and installation. In case of separate parties involved, Customer shall provide service experience of completed joint venture projects, and/or projects in (factory acceptance testing) FAT stage or installation stage.

4.3.2 SUPPLIER INSTALLATION EXPERIENCE

Cable installation company should have project experience as below:

a. Installation of a similar cable system in at least three projects for EU offshore transmission system developers, transmission system operators or utilities.

   As an alternative to such service experience within the EU/EEA, similar experience with Japanese, Australian, US/Canadian, or South-Korean, UK or other will be considered.

b. At least 1 (one) or more references for completed cable laying / burial operations of min. 220 kV 800mm² submarine cables of cumulative length of >100 km during the last 10 years.

c. At least 3 (three) reference for offshore jointing operations, such as cable end recovery, joint deployment, and burial of min. 220 kV 800 mm² submarine cables during the last 5 years

d. At least 3 (three) reference for either self-conducted or supervised cable pull-in operations at landfall with min. 220 kV 800 mm² submarine cables during the last 5 years

4.3.3 Supplier experience requirements for HV Cable and Accessories

The Customer shall submit a reference list of dates, quantities, and clients for each cable and accessory type being offered.

a. General Manufacturing experience

   The cable system types (cable, joints, terminations, split box, clamps, link boxes etc.) being offered shall have a minimum of a five years proven service record. A list shall be provided outlining the projects and clients the manufacturer has supplied in the last five years.

b. Specific Manufacturing experience at manufacturing facility proposal

   At least five years production experience in the cable manufacturing facility is required.

4.3.4 Supplier experience for duct Manufacturer and installers

In case of ducts being installed in landfall section, the duct manufacturer shall have:

1) At least 10 years' experience in the production of the range of the ducts and fittings specified i.e., the "product''.
2) Service experience:
   a. Installation of the product in at least one EU electricity utility
   b. with a service experience of the product range of at least 5 years duration in three EU electricity utilities of at least 1,000 km.

   As an alternative to such experience within the EU, similar experience with UK, Japanese, South Korean, Australian, or US/Canadian utilities would be considered.

At least 5 years production in the proposed factory is required.

4.3.5 Supplier experience requirements for fibre optic preforms

The Customer shall meet the following requirements:

a. General Manufacturing Experience of Fibre optic preforms

At least 10 years of experience in the production of Fibre optic preforms for subsequent drawing into single mode optical Fibre conforming to ITU-T Specification G.652.D.

b. Specific Manufacturing Experience of Fibre optic preforms at Manufacturing Facility Proposed for this Project

At least 5 years of production experience at the particular preform manufacturing facility is required.

4.3.6 Supplier experience requirements of single mode fibre

The Customer shall meet the following requirements:

a. General Manufacturing Experience of Single Mode Fibre

At least 10 years of experience in the production of Single Mode Fibre.

b. Specific Manufacturing Experience of Single Mode Fibre at Manufacturing Facility Proposed for this Project

   At least 5 years of production experience at the cable manufacturing facility for the production, drawing and spooling of Single Mode Fibre to ITU-T Specification G.652.D is required.

c. Service Experience

   This shall be a minimum of 5 years of service experience associated with supply of Single Mode ITU-T G.652.D fibre and accessories in at least three EU/EEA Countries.

   As an alternative to such service experience within the EU/EEA, similar experience with Japanese, Australian, US/Canadian, or South Korean or UK will be considered.

4.3.7 Supplier experience requirements for FO based monitoring system

This section contains supplier experience requirement for FO based cable monitoring system, including distributed temperature sensing (DTS), and distributed acoustic sensor (DAS) system.

The Customer shall comply with each of the requirements set out below:

a. The DTS system manufacturer shall have at least 5 years' experience in design, manufacture, and installation of DTS systems applicable to the cables industry covering both land and submarine installations pertaining to HV cables,
b. Continuous satisfactory service experience of at least 12 months for the product on offer:
   i. Installation of the product in at least three EU/EEA countries. And,
   ii. with service experience of at least 5 years duration in these EU/EEA countries.
c. As an alternative to such experience of b(i) and b(ii) above within the EU/EEA, similar experience with UK, Japanese, Australian, South Korean, or US/Canadian utilities will be considered.
d. At least 5 years production of the product in the particular plant proposed is required, although if the particular plant proposed is relocated and continues using substantially the same workforce the combined production experience of both plants will be considered
e. The product proposed as following this specification shall be manufactured in the same plants which produced the products cited as meeting the service experience requirements outlined.

The Customer shall ensure that the DTS and DAS system manufacturer retains a workforce suitable for the manufacture of the product. The Customer shall on request supply the details of levels of qualification attained by key employees involved in delivering of the project, minimum expected qualifications include Master level education in the relevant field and/or 5 years' experience.

4.4 Health, Safety, Environment Related Requirement

For all submarine cable systems, the design and construction elements shall be in accordance with applicable Irish and EU Health and Safety Regulations (ISO14001, ISO 45001) and Approved Codes of Practice.

In undertaking the project, the Customer shall always be aware of and comply with the applicable international and national Health & Safety legislation, Approved Codes of Practice and Industry Standards and all subsequent modifications or amendments in relation to same.

The selection of material and processes throughout the cable project stages, from cable design, manufacturing, transportation and installation, operation, and to decommissioning, shall be conducted with due regard of health, safety, environmental and quality aspects. EirGrid may not accept any cable system materials which breach the EU Reach Directive. All cable system components which contain chemical compounds shall be declared in the hazardous materials and safety datasheets. The Customer shall evaluate the risk impact and shall provide a Register of materials and a letter declaring that the proposed cable system and related spares are following the EU Reach Directive.

A risk management plan is required to describe, communicate, and document the objectives, responsibilities and activities specified for assessing and reducing risk of offshore activities to an acceptable level. Risk management should follow DNV-RP-N101.

4.5 Quality Assurance Plan

The Customer shall submit a detailed Quality Assurance Plan prior to the design phase of the project. The Customer shall maintain and submit quality certification documents relating to the products and systems supplied for the cable system, refer to OFS-GEN-004.

The Customer Quality Plan shall demonstrate, that the control measures adopted at the design and construction stage will result in successful commissioning and long-term, expected, performance of the built circuit. The Quality Plan shall address, but not limited to, the elements in the following list:

1) Competence of key staff (e.g., engineers responsible for material, electrical, mechanical, thermal, civil, installation, testing, maintenance; inspector, auditor, quality controller. This shall detail the experience and qualification of engineers/Customers and proven track record.

2) Details of Quality Assurance Certification, refer to OFS-GEN-004..

   Each manufacturer and Customer shall have a Quality Assurance System conforming to ISO 9001 latest version. The Customer shall ensure that the same requirements are applied to products, systems and services supplied by sub-Customers and suppliers.

3) Material selection, sampling, handling, testing on site and testing off site.

   The routine tests and inspections for supplied materials and processes shall be specified in the Customer's Quality Plan. Qualified staff, including testing personnel, operator, quality controller, jointer, shall have competency certificates or training evidence to use the specific equipment. All testing and measuring recording equipment and the installation tools, as required, shall be calibrated by accredited calibration bodies. The valid calibration certificates should contain the expired date, the next calibrate date and full detailed calibration records. All materials and workmanship shall be of a suitable type and quality to ensure that the cable system will operate satisfactorily in accordance with EirGrid Specifications.

4) Site work audit and Control Plan.

5) Method statements for the transportation and installation of the cable and fibre system All cable and fibre system installation work shall be carried out in accordance with the manufacturer's approved installation methods. The Customer shall advise EirGrid well in advance of commencement of any installation work so that a representative may be made available to witness the works.

4.6 INFORMATION AND DOCUMENT SUBMISSION

The following documentation specific to submarine cable projects shall be submitted by the Customer to EirGrid, including but not limited to:

1) Design related documents:

   a. Cable system reliability and availability report

   b. Cable rating calculation for all relevant installation scenarios along the cable routes

   c. Cable sizing selection

   d. Cable and accessories development tests results

   e. Landfall design

   f. J-tube design considerations

   g. Route selection and design prior to submission of Planning application

   h. All basic "special" design assessments related to submarine cable, e.g., Bathymetry, magnetometer/gradiometer, sub bottom, acoustic doppler, current profiler, drop down video.

   i. Route and cable burial risk assessment and protection design

   j. Cable interface design

   k. Cable alignment drawings

   l. Crossing drawings

   m. On bottom stability analysis

   n. Free-span analysis

   o. Pre-lay and post lay intervention details

   p. Installation drawings (trenching, J tube etc.)

   q. Cable pulling tension calculations

r. As laid/as built drawings
s. Designer's Hazard Identification (HAZID), Hazard in Operation (HAZOP), Hazard in Construction (HAZCON)
t. Electrical single line diagram and protection schematic
u. Protection coordination study
v. Insulation coordination study
w. Short circuit calculations
x. Sheath voltage limiter sizing calculations (if applicable)
y. Cable system earthing and bonding
z. Electromagnetic influence study
aa. Fibre optic loss study
bb. Cable repair and splicing procedure
cc. Cable sealing procedure
dd. As laid and as built reporting

2) Material related documents:

a. Cable and accessories material specification and development test results
b. Cable and cable bonding technical schedule
c. Cable cross section drawings
d. Final cable order lengths
e. Joint drawings (for each type)
f. Joint and joint earthing technical schedules
g. Full sheath bonding/earthing scheme including phasing at each joint and termination
h. Bonding lead cross section drawing and technical schedule
i. Transition joint bay drawing and technical schedule
j. Link box drawings, technical schedule, and general arrangement (including distances from joint)
k. Termination drawings (for each type)
l. Termination and termination earthing technical schedules
m. Cable clamp drawings, arrangement and schedules
n. Cable containment and support (e.g., cable ladder / tray) technical schedules and drawings

o. Proposed cable pulling head / stocking technical schedule
p. Cable hang-off drawings (for each type) and associated technical schedule
q. Cable bend stiffener technical schedule & drawings
r. Cable mechanical anchor technical schedule and drawings
s. Cable mechanical protection technical schedules and drawings?
t. Proposed cable lubricant for duct installation (if applicable)
u. Duct technical schedule in landfall section (if applicable)
v. FO cable and accessories (including splice boxes) drawings and technical schedule
w. Fibre termination and splicing schedules
x. Distributed temperature sensor (DTS) system (including rack) drawing, technical schedule, and schematic
y. Distributed acoustic sensor (DAS) system (including rack) drawing, technical schedule, and schematic if applicable.
z. Certification junction box as per EN 60529:1991

3) Qualification documents:
   a. Design qualification test certificates, report
   b. Production line qualification certificates
4) Manufacturing documents:
   a. Relevant project quality control records
   b. Testing and inspection plans and requirements
   c. Production tests record
   d. Non-conformities record
   e. Raw material properties and quality control
   f. Storage record
   g. Trace and track management system
5) Installation document:
   a. Copies of approved maritime permits and consents covering installation & O&M phases
   b. Environmental management plan
   c. Cable route survey and preparatory procedures

d. All related procedure including (but not limited to) load out ,transportation, trans-spooling, laying and catenary management, pull-in preparation, pull-in activity, jointing processes and wet store
e. All related technical assessments including (but not limited to) trans-pooling ,normal lay Shore pull, platform pull-in shore pull
f. Weather assessment manual Mobilization and calibration report
g. Jointing certificates and QA forms
h. Cable protection plan
i. Cable crossing plan
j. Cable pulling tension records (electronic file and paper print outs)
k. Evidence to demonstrate compliance with authority permits and consents, e.g., drop down video (before and after cable installation)
l. Cable installation and burial depth records, for entire route, including landfall
m. FO route and splicing records
n. Reinstatement/rehabilitation works as required by authorities after installation
o. Cable abandonment and recovery, wet storage, repair plan
p. Operation and maintenance manuals
q. Decommissioning plan
r. business continuity plan and an emergency preparedness plan

6) Testing reports/certifications, refer to OFS-GEN-004.:
a. Pre-qualification tests
b. Type tests
c. Production tests
d. Factory acceptance tests
e. Routine tests
f. Sample tests
g. Hand-over tests
h. Onsite acceptance tests
i. Fibre optic tests
j. Records of all tests as per IEC standards
k. Special tests and other tests not categorised in above mentioned tests

7) Safety information:
   a. Safety organisation chart
   b. Safety file
   c. Evidence of appointment of Project Supervisor Design Process (PSDP) and Project Supervisor Construction Stage (PSCS)
   d. Signed certificate / letter stating full compliance with all Irish Construction and Safety regulations and including all risk assessments for the cable system proposed
8) References, warranties, other:
   a. Service experience list of projects
   b. Service experience list for material manufacturer
   c. Service experience list for material installers
   d. Updated manufacturers training certificate for jointers and installers
   e. Training plan for EirGrid nominated staff
   f. Curriculum Vitae of jointers and training instructors
   g. Details of storage facilities to be provided for spares
   h. Details of shelf life of spares items.

5 Cable system Performance Requirement

5.1 Design Lifetime and Reliability

The minimum design life for the cable, including fibre optic cables, all accessories, ducts and ancillary components is 40 years.

5.2 Electrical Requirement

Below the electrical requirements of cable and accessories shall be met:

a. electrical stress across the XLPE insulation:
   - at conductor screen: ≤ 8kV/mm
   - at insulation screen: ≤ 4kV/mm

   Cables with stresses greater than 8 kV/mm at the conductor and/or 4 kV/mm at the outer surface shall require a prequalification test per IEC 62067.
b. System withstands voltages requirement, refer to OFS-SSS-400 Specification.
c. Short circuit current requirement, refer to OFS-SSS-400 Specification.
d. Insulation co-ordination study
e. Magnetic fields/interference

5.2.1 Thermal requirement

Below the thermal requirement of cable and accessories shall be met:

a. The maximum temperatures admissible for the conductor per IEC 62067:

b. The maximum temperatures admissible for the metallic sheath under short circuit condition shall be as per IEC 61443

c. Thermal conductivity measurement of insulation and other non-metal components in the cable.

5.3 Mechanical Requirement

Submarine cables shall be designed to be able to withstand mechanical forces raised during any project stages. Mechanical forces raised during processes below shall be evaluated and considered in cable system design, including cables, accessories, and ancillary components:

a. pulling, bending and torsion forces during cable manufacturing process

b. cable crush load in storage

c. cable handling type and number of cycles as well as expected forces during cable transportation process

d. bending radius, pulling and compression forces in cable installation process

e. bending cycles and radius of single cores and FO cables in cable installation stage

f. induced mechanical (bending, torsion) forces under short circuit conditions

g. thermo-mechanical stress during cyclic loading of the cable operation

h. bending radius, pulling and compression forces during the cable recovery & repair process.

5.4 Environmental Requirement

Marine flora and fauna mutual impacts need to be considered in cable design, installation plan and cable operation activities.

Environmental Impact Assessment and surveys shall be shared with EirGrid for review and shall be done in accordance with Cigré TB 883, section 2.5 and 4.6.

6 Cable System Design

6.1 General Design Requirements

The design produced by the Customer shall comply with EirGrid functional requirements and shall make adequate provision for:

1) Performance to the required submarine cable system requirements including dynamic current rating under cyclic loading and short circuit rating

2) Safety of operation and maintenance personnel

3) Safety of members of the Public
4) Reliability and continuity in service
5) Ease of inspection, maintenance and decommissioning
6) Ease and clarity of operation
7) Avoidance of spurious alarms
8) Ability to withstand the service conditions specified
9) Precautions to minimise fire risk.

6.2 OFFSHORE CABLE ROUTE DESIGN

6.2.1 CABLE ROUTE STUDY

Offshore cable route study shall be carried out according to DNVGL-RP-0360, clause 3.3 and Cigré TB 883 section 3.

Cable project specific requirements should be considered when conducting a cable route study. These should also include consideration of the construction phase, including marine operations for lay and burial, equipment to be used and envisioned burial depth. Information shall be captured in a geographical information system or similar database.

The output of the cable route study should include possible cable route(s) and the specification of the cable route surveys.

6.2.2 CABLE ROUTE SURVEY

Offshore cable route survey shall be carried out according to DNVGL-RP-0360, clause 3.4 and Cigré TB 883 section 4.

Detailed data shall be obtained for the total length of the planned cable route, covering a corridor of sufficient width to provide adequate information for design of the final cable route.

Possible route adjustments due to subsequent findings shall be considered when performing the surveys and determining the width of the cable corridor.

All survey data shall be geo-referenced to allow overlaying of subsequently obtained data, e.g., in a geographical information system.

6.2.3 CABLE ROUTE ENGINEERING

Offshore cable route engineering shall be carried out according to DNVGL-RP-0360, clause 4.5 and Cigré TB 883 section 3.

Information obtained from cable route study and cable route survey should be used in the detailed cable route engineering process.

Key parameters and constraints should be defined, preferably in consultation with the cable installer.

When selecting a cable corridor, the cable installation activity shall be considered, but it equally important to consider the long-term operation, maintenance and planning for surveys, intervention works and repairs.

The minimum space required on the seabed for repairs using an omega joint solution to ensure the operation will not interfere with adjacent subsea assets is to be the summatory of:

a. the local water depth plus
b. the freeboard of the repair vessel plus
c. the length of cable kept on deck during the repair plus
d. the length of the ‘crown’, being the bend in the cable at the top of the omega joint which will typically be deployed to the seabed using a quadrant.

EirGrid minimum requirements for cable corridor width for a single submarine cable is indicated in Figure 1

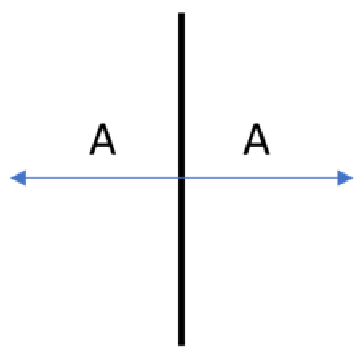

Figure 1 - Single cable circuit corridor width requirements

Where A is the larger of minimum 50 meter and 3 x Water depth.

The Customer should develop a specific risk assessment to ensure these minimum requirements sufficiently de-risk the submarine cable installation and operation activities.

Based on the identified constraints, the cable route should be designed and optimized, preferably using a geographical information system (GIS) or similar route engineering tool.

The cable route should be further refined through a cable burial risk assessment and burial assessment study, considering risks such as – but not limited to – fishing activities, moving seabed, seabed erosion or navigation. Specific aspects are addressed in the following subsections.

After the final cable route has been agreed, the nominal length shall be adjusted.

6.2.3.1 PARALLEL ROUTING OF CABLES

In the cable route planning and design of adjacent cables, the Customer shall consider and ensure sufficient space for repair and maintenance. In particular the risks associated with the fault location, recovery, repair and deployment of the repair bight on the seabed – while also bearing in mind proximity to turbines, OSP's and any third-party infrastructure.

When several cables are running in parallel, consideration should be given to the following, as a minimum:

a. Electrical System design.
b. Stakeholder requirements:
c. Impact of EMF on flora, fauna and other assets.
d. Safeguarding of Transmission Asset Integrity.
e. The need to safely install, repair and maintain the cable and asset adjacent to the submarine cable without posing an unacceptable risk to the submarine cable and adjacent asset.
f. The relationship between burial depth and cable spacing.
g. Risk reduction for multiple cable hits by dragged anchor or fishing gears
h. Potential cable repairs (i.e. for multiple circuits, spacing suitable to repair the submarine cable without compromising the minimum design bend radius or tensile loading criteria, according to the manufacturers repair methodology, while catering for the actual water depth in which the cable is laid).
i. Thermal interdependency.

EirGrid minimum requirements for cables corridor width and cable spacing for multiple submarine cables is indicated in Figure 2 and Figure 3

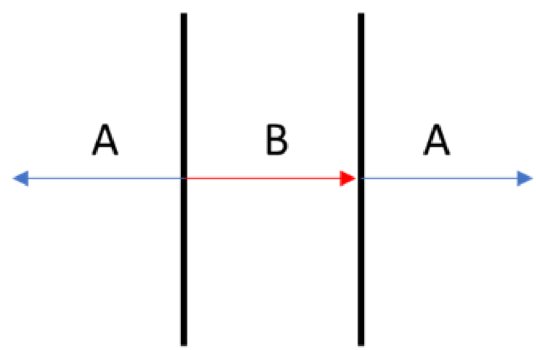

Figure 2 - Double cable circuits corridor width requirements

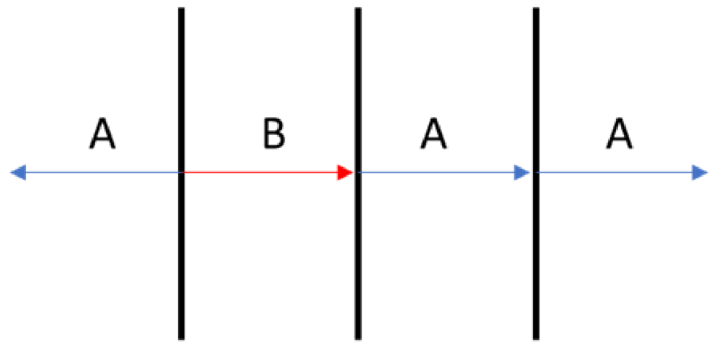

Figure 3 - Multiple (3+) cable circuits corridor width requirements

Where A is the larger of minimum 50 meter and 3 x Water depth and B is minimum 50 meters.

The Customer should develop a specific risk assessment to ensure these minimum requirements sufficiently de-risk the submarine cables installation and operation activities.

6.2.3.2 PROXIMITY TO EXISTING INFRASTRUCTURE

When cables approach or run in parallel with existing or planned 3rd party infrastructure, the potential consequences should be assessed, considering development, construction, maintenance (especially repair) and decommissioning activities of both parties. Information about planned or existing infrastructure should be exchanged between the parties concerned as early as possible.

A written proximity agreement between Customer (on behalf of EirGrid) and owner/operator of the existing infrastructure is required.

Exclusive zones and safety distance to nearby existing infrastructure need to be considered and agreed in the cable route design.

Stakeholders in a discussion on proximity limits between submarine cables and offshore wind farm structures are required and shall agree safe and appropriate solutions to determine how much sea room is actually needed to efficiently and safely execute a cable repair.

The four key points to consider assessing the sea-room required by a cable ship are:

a. Fault location
b. Cable recovery
c. Cable repair
d. Re-deployment

When considering proximity distance requirements for a cable two important concepts shall be examine:

a. Working Zone, applied either side of the subsea cable

   and

b. Hazard Area, applied around the cable repair vessel

The Working Zone is required either side of the submarine cable to enable safe access for cable maintenance and operation activities by a suitable vessel. The Working Zone for traditional repair scenarios is required to be 500m either side of the existing subsea cable. This is based on the expected area required to undertake cable fault location using trailed electrodes, grapnel and final bight deployment operations. The mentioned distance also considers the following points:

e. Proximity of other adjacent developments (i.e. oil and gas)

f. Proximity of hazards, density of traffic and navigation schemes

g. Type, size and manoeuvrability of vessels

h. Support vessels

a. Cable type and existing burial status/protection.

b. Alternative repair options, such as a lay-through repair, or adjusted final bight location.

c. Predicted prevailing metocean conditions (wind, wave, current, tides) etc.; and

d. Seabed type.

The Hazard Area is independent and in addition to the Working zone and take in consideration the rea-room required by the vessel undertaking cable operations to reduce the risk of work in close proximity of the Wind Turbine structure. The Hazard Area depends on the overall length of the cable repair vessel and it is recommended a minimum 250m radius around the vessel is considered for the purpose.

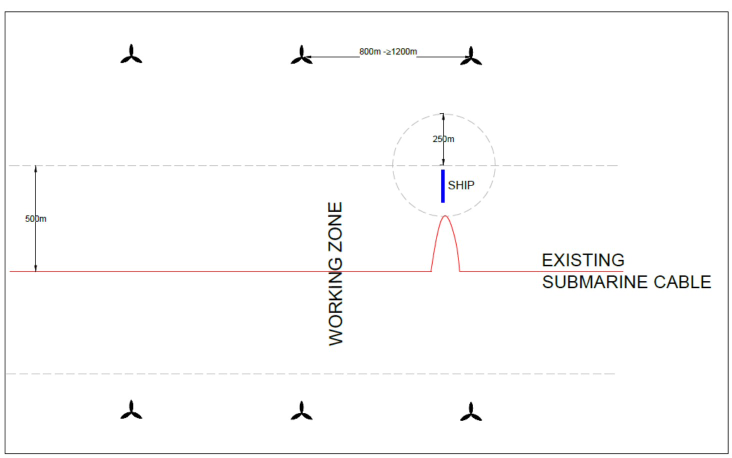

Figure 4 - Working Zone and Hazard Area illustration

6.2.3.3 Crossing of Existing Infrastructure

Assessment of cables crossing existing infrastructures (pipeline, telecommunication cables, power cables) should be assessed separately, based on actual conditions.

Information about the proposed crossing shall be exchanged between the parties concerned as early as possible.

A written crossing agreement between Customer (on behalf of EirGrid) and owner/operator of the existing infrastructure is required.

Considerations concerning the exact crossing location and the design of the crossing shall refer to the requirement in DNV-RP-0360 clause 4.5.4 and Cigré TB 883 section 3.5 and 7.4.

Crossing of any existing or new infrastructure shall not lead to derating of the cable.

6.3 CABLE INTERFACE DESIGN

6.3.1 INTERFACE ON FIXED OFFSHORE UNIT

6.3.1.1 INTERFACE DESIGN AT OFFSHORE SUBSTATION PLATFORM

The design of the interface between a submarine cable and fixed offshore platforms shall consider conditions and limits during and after installation. An optimum path of the power cables should be determined considering factors applicable for the specific project.

The offshore unit should meet the requirements below:

1) Access of personnel and transfer of cable installation, termination and testing equipment to the offshore unit shall be considered in this design element.
2) The aim would be to avoid the creation of confined space as much as is possible. Where entry into confined space is required, this should be considered for persons and equipment to be used, including potential requirements for emergency escape.
3) The clearance between cable deck and main deck shall be sufficient to carry out the cable pull-in, re-pulling, and handling operations.

The interface between cables and the offshore units should fulfil requirements below:

1) The risk of scour around the foundation of an offshore unit should be assessed to aid cable interface design.
2) The interface should allow adequate heat dissipation and maintain cable temperatures within acceptable limits. Dynamic cable rating concept is considered not to be applicable for this part of the installation. Design of the interface should consider cable steady sate peak loading situation.
3) Stabilize and protect the cable in the vicinity of the platform's substructure.
4) Be easily installed.

An optimum path of the cables from the seabed to the hang-off: External J-tube, I-tube, internal J-tube, or J-tube less, should be determined based on consideration factors applicable for the specific project, considering environment impacts, protection from vessels, location of the cable entry, and corrosion rate of the structure.

Design requirements of the interface components, such as J-tube and I-tube, Bellmouth, J-tube less interface, bend stiffener, bend restrictor, entry seal, latching/anchoring mechanism, and tube centralizer, refer to requirements in DNVGL-RP-0360, clause 4.7.4.

6.3.1.2 Cable Installation Design at Offshore Interface

Cable installation design at offshore interface shall meet requirements below:

1) In the vicinity of the offshore unit where the cables terminate, the cable lay-out should be optimized, avoiding congestion, and enabling installation, including burial and non-burial protection.
2) Restrictions at / near offshore units like jack-up “cable free” zones shall be respected. Conversely, “no jack up” zones should provide adequate space for cable routing. Coordination with the offshore station designer is required.
3) Congestion of cables and J- or I-tubes should be avoided to aid installation and maintain cable temperatures within acceptable limits.
4) Supplier should give recommendations on design of pull in through J tubes: direct pull in, re-pull, or pull in with bending restrictor.
5) Routing of single core cables above the hang-off unit refer to requirements in DNVGL-RP-0360, clause 4.7.2.7.

6.3.1.3 HV Cables Routing and Fixing in Offshore Platform

Route design of HV cables in offshore platform refer to DNVGL-OS-D201 offshore standard for electrical installation. Minimum requirements are as below:

1) The cable installation shall be protected against fire, fire spreading, thermal, mechanical, corrosive and strain damages.
2) Cables must be installed and secured in such a way that longitudinal expansion is divided over the full length of the cable and does not occur only at a few points.
3) Support and fixation of the cables and cable runs shall be done according to DNVGL-OS-D201 section 3.5 Support and fixing of cables and cable runs.
4) Fixing devices should be made of steel adequately protected against corrosion or non-metallic materials with appropriate properties. Braid or armour of lead, bronze or copper should not be installed in contact with aluminium alloy structures, except in dry indoor spaces.
5) Safe access ladders and work platforms should be provided for points of the cable run where later inspection or maintenance is planned or foreseen.
6) The internal bending radius for the installation of cables at all the installation locations during the complete lifetime shall not exceed the limit defined by the manufacturer.
7) Cables shall be fixed by cable cleats except when carried in pipes. Cable cleats for fitting single- and multiple-conductor submarine cables shall be designed according to IEC 61914 and guidance in Cigré TB 669. Tolerance between cable/cable cores and cleats shall be considered under mechanical thermal expansion conditions.
8) Spacing between the cleats shall be suitably chosen according to the type of cable (considering the possible mechanical movement under SC failures), and the probability

of offshore unit movement and vibration at the actual point of installation. Adequate proof shall be given for the selected spacing, otherwise values defined in table 4 of DNVGL-OS-D201 shall be used.

9) HV power cable and LV cables should be grouped separately and not be installed on the same cable tray, to avoid magnetic field interference. Segregation between power cables and data cables should follow guidance on EN 50174-2 and BS 6701.

10) Design of the cable route and cable trays, cable fixation and supporting units should be done that the cable runs do not take up hull forces caused by the offshore unit's movements, different load conditions and temperature variations, see requirement in DNVGL-OS-D201.

11) The end of the cables shall be sealed to prevent the ingress of water when submerged. Cable splices (both factory and field spices) shall not be pulled into or through the j tube.

12) J tube bell mouth shall be sealed/closed in order to prevent marine growth and shall be opened only before the J tube pull activity commence. A scrapper shall be run to make sure there is no marine growth if the J tube was bell mouth cover was open for long time before pulling activity.

6.3.2 Interface on Land-based power system

The onshore jointing location (sea/land transition joint bay) shall be designed to:

1) Provide a safe and stable temporary working area.

2) Transition Joint Bay shall have an adequate earthing system and be fully incorporated in the cable system bonding design.

3) Cable perpendicular stainless bars and cleats shall be incorporated in the transition joint bay so to avoid cable movement during short circuit events and/or other cable movements.

4) The transition joint bay shall be equipped with a PD monitoring facility (integrated capacitive or capacitive-inductive PD sensor). There is no requirement for constant online monitoring, the purpose of this is to have a test facility for maintenance to be used during the cyclical maintenance PD monitoring activity. It is anticipated that no LVAC supply will be required.

5) Have hard stand spaces for winches and cable drum for adequate overlength of cables to be pulled in

6) Allow securing (anchoring) the cables mechanically.

7) Allow for the provision of a conditioned environment for jointing activities (e.g., dewatering, air conditioning).

8) Enable cable commissioning and testing.

9) Provide adequate accessibility for future inspection and operation activities.

Jointing of subsea and land-based cables at the sea/land transition joint bay (TJB) shall be carried out in accordance with the procedure developed for the particular cables and approved by the cables' manufacturers. After jointing of subsea and land-based cables, the sea/land transition joint bay shall be closed and secured.

Transition Joint Bay design and installation shall be done in accordance with Cigré TB 883, section 3.6 and 6.7.

6.4 Cable protection design

6.4.1 Burial cable protection design

6.4.1.1 Burial assessment

Where the submarine cable can be buried in seabed, burial assessment study shall be performed according to Cable burial risk assessment methodology (CBRA) such as the Carbon Trust CTC 835 and associated Application Guide for the specification of depth of lowering (17 December 2015), or other comparable risk assessment methodology. For cable protection requirement Cigré TB 883 section 3.5 and 5.4 have to be followed.

Risks along the cable routes shall be determined and evaluated. The optimum depth of burial shall be determined by applying a risk-based approach such as the above, considering the following:

1) external damage such as fishing gear, dropped or dragged ship anchors, dredging activity, and other dropped objects;
2) movement or exposure of the cable due to sediment movement, scour, seismic activity, sand waves, and eventually free spanning of a cable length.
3) Magnetic fields and temperature rise in the seabed may also play a role in specifying the target depth of lowering, and the protection level, any local regulations about magnetic fields and temperature rise in the seabed shall be considered when specifying the target of depth of lowering and the protection level.
4) Special precautions are needed in areas with a dynamic seabed (sand waves or with a dynamic shoreline). Additional protection (e.g., rock berm or other forms of remedial protection) may be needed, alternatively cables may be installed deep in the seabed;

6.4.1.2 Burial Design

Burial design for cables should determine the trench geometry and dimensions along the entire cable route including the main parameters, trench width, depth of lowering and depth of cover.

Detailed engineering assessments should determine the feasibility of the design burial depths and whether pre-sweeping or pre-lay trenching may be required.

Burial design and methodology shall consider environmental impact assessment report from the competent authority and the Customer is responsible for obtaining the necessary approval from the all required stake holders.

6.4.1.3 Burial Technology Requirement

The range of suitable burial techniques should be assessed based on project specifications, among Jetting/fluidisation, ploughing, mechanical cutting and open trench dredging.

Criteria of choosing the burial technique should cover water depth, currents and waves, seabed and soil properties, environment impact, cable parameters, burial depth requirement, cable lay and burial sequence/combination, and potential burial equipment capability and availability.

Selection of the cable burial equipment should consider seabed condition, cable properties and other boundary conditions, laying and burial combination, mode of movement / burial tool carrier system, and anticipated performance. Preliminary decision for a specific approach should be subjected to a systematic review of all risks in the different phases of the project.

Specification of burial depths and suggested burial technique should be reviewed, e.g., by an experienced installer, regarding feasibility and appropriateness.

6.4.2 Non-burial Cable Protection

6.4.2.1 Non-burial Cable Protection Locations

Submarine cable should always be buried unless specific circumstances impose the installation of the asset non-buried.

In all these cases the Customer should provide a report and design risk assessment to demonstrate not undue risk is being taken with the non-burial solution.

Non burial cable protection measures shall be designed to protect the cable in specific locations:

1) In vicinity and at interface with offshore structure.
2) in the immediate vicinity of offshore units where burial is not practical.
3) Across boulder, cobble, or gravel fields or in very hard rocky areas where burying is not feasible or economic or target burial depth cannot be guaranteed due to various reasons.
4) In location where cable crossing another infrastructure, e.g., another cable or pipes.
5) In areas affected by mobile sediments and burial below the mobile layer (lowest seabed level) cannot be achieved;" Bullet as written could include vast majority of non-bedrock
6) Areas where during installation the selected burial method did not perform, and the cable is left laid on the seabed.
7) At cable repair (joint) locations.

6.4.2.2 Non-burial cable protection techniques and requirements

The most appropriate non-burial cable protection technique (or combination of techniques) should be selected from the available options, which may include tubular pipes/ducts, concrete mattress, and rock replacement.

Design of cable non-burial protection should be based on project specific requirements, and should meet below requirements:

1) Acceptable reduction of current rating
2) Provision of protection, support, and stability
3) Flexibility regards to repair or replacement
4) Corrosion resistance.

6.5 LANDFALL CABLE ROUTE DESIGN

For landfall cable route design F Cigré TB 883 section 3 and 4.5 have to be followed.

6.5.1 CABLE CIVIL WORKS IN LANDFALL

For cable civil works in landfall area, duct, couplers, and duct installation requirements refer to Part 4 of the EirGrid land cable functional specification.

Site access by land and sea shall be carefully designed. Seasonal restrictions are to be considered.

6.5.2 MINIMUM CLEARANCES OF CABLES AND DUCTS

Design of minimum clearance of cables and ducts in landfall section shall follow the requirements in EirGrid Onshore Cable Functional Specifications.

6.5.3 OPEN CUT TRENCH

For requirements of the open cut trench refer to EirGrid Onshore Cable Functional Specifications.

6.5.4 HORIZONTAL DIRECTIONAL DRILLING

In case of horizontal directional drilling (HDD) applied in landfall section, design of HDDs and HDD trajectories shall be done based on project specific conditions. Customer shall ensure the following is carried out:

1) Construction HDD design based on specific site investigation results
2) Drilling methodology suitable to the project specific conditions
3) Assessment of the viability of the conceptual HDD design through hydrofracturing modelling, drilling forces modelling, and calculation of duct installation forces
4) Determine equipment requirements by modelling drilling forces and duct installation forces for the HDD
5) Programme for the HDD works
6) A detailed Dynamic risk assessment (DRA) of the HDD, including cable current rating, HDD safety, and environmental assessment.
7) Identify any additional risks, mitigations measures, or opportunities for the landfalls.

6.5.4.1 HDD ENTRY SITE LOCATION

The decision where to place the HDD entry site should be thoroughly evaluated considering points:

1) Drilling profile
2) Rig/pipe site space requirements, availability, and accessibility
3) Risk of high water, erosion, and damage to the equipment
4) Environmental factors such as drilling fluid and soil management.

6.5.4.2 HDD PROFILE DESIGN

The HDD profile shall be designed considering the points:

1) Min. radius of curvature of drill rods
2) Entry angle and exit angle
3) Future landfall erosion profile
4) Ground conditions
5) Min. water depth at exit to accommodate cable lay barge, when required
6) Onshore/offshore cable boundary limits.

Calculations need to be undertaken to determine the loads required to launch the cable duct from the stringing site to the transition joint bay and to determine the anticipated pull loads to assist with the selection of the HDD equipment. The anticipated launch and installation loads should be within acceptable limits of the duct mechanical properties.

6.5.4.3 DUCT DESIGN REQUIREMENTS

Requirement of the duct used in HDD shall meet the requirements in section 6.4 of EirGrid Onshore Cable Functional Specifications, except for the required duct dimensions.

Ducts and their associated couplers shall be designed as an integral system.

The internal diameter and wall thickness of the duct required for submarine cable in land fall will be dependent on the diameter of the cable pulling head and the thermal dissipation of the cable when it is operational. As a general rule, the internal diameter of a duct should be (minimum) 1.5 times the cable outer diameter, as defined in Cigré TB 770.

6.5.4.4 HDD CONSTRUCTION PROCESS

HDD construction process shall follow the guidance in Cigré TB 770 and TB 883.

6.6 Current Rating and Cable Sizing Selection

6.6.1 Cable current rating

The current ratings shall be calculated in accordance with the current edition of IEC 60287 and IEC 60853 parts 2 and 3 latest editions with the actual conditions and the actual environmental conditions in project specifications.

The recommendations of Cigré TB 610, Cigré TB 640, Cigré TB 272, and Cigré TB 880 shall be considered in the current rating calculations.

Below requirements and limitations of the current rating calculation shall be met:

1) Accredited simulation tools shall be applied in cable current rating calculation, in case of self-developed calculation methods, methodology description and verification shall be provided by the Customer.
2) Cable current rating estimation shall cover all the valid installation scenarios in the selected cable route, such as, but not limited to: buried in seabed, in water, cable crossing and parallel installations, J tube, monopile, ambient air, CPS system, converging cores (if relevant), in trenches and troughs and HDD ducts in landfall, etc.
3) For dynamic rating calculation, the Customer may base this on project specific parameters, such as the wind farm load profile, burial depths, soil characteristics and environmental conditions as per the project specific design basis. The load profile shall consider cable pre-conditioning as well as the maximum foreseeable load duration The dynamic rating calculation shall consider the entire life time of the assets, and take into account known anticipated changes to the design basis, such as coastal erosion at land fall, sand waves or moving seabed and climate change. Customer shall document how these factors have been taken into account in the design basis.
4) In both steady state and dynamic rating, maximum conductor temperature shall not exceed the max designed cable conductor temperature defined in IEC 60287-1-1.
5) Consideration of thermal mutual impacts with adjacent or crossing services.
6) Any additional regulations related to project specifications shall be respected.

6.6.2 Optimization of cable sizing

Life cycle costs for the cable system shall be considered in the selection of cross section. Optimization of the cable sizing shall take due account of the CAPEX costs as well as the OPEX costs as per the following section.

6.6.2.1 OPEX CALCULATION

The Euro/Mwh value, with due consideration of inflation to be used to calculate the electrical losses element of the OPEX cost of the HV cable. This Euro/Mwh value shall be advised by EirGrid.

$$KWh\ per\ year = \frac{3 * \left[(I_{pmd})^2 * R\right] * LLF * H}{10^3}$$

Equation 1 kWh Per Year

Where

$KWh = Kilowatt\ Hours$

$I_{pmd} = Peak\ Annual\ Single\ Phase\ current$

$R = total\ Resisitance\ of\ Circuit = R_{perkm} * km$

$LLF = Loss\ Load\ Factor\ See\ Below$

$H = number\ of\ hours\ per\ year = 8{,}766$

$$LLF = \frac{P_{Lavg}}{P_{LPeak}}$$

Where:-

$$P_{Lavg} = \frac{\sum_{n=1}^{T}(In^2 * R)}{T}$$

$$P_{Lpeak} = (I_{Peak})^2 * R$$

Equation 2 LLF Calculation

Where:

$P_{Lavg} = Average\ Powerloss\ in\ kw\ over\ a\ time\ period\ (1\ Year)$

$P_{LPeak} = Peak\ loss\ in\ kw\ during\ that\ time\ period\ (1\ Year)$

$H = number\ of\ measrements\ take\ i.e\ 1\ per\ hour\ over\ 24\ hours\ H\ number\ = 24$

$In = Load\ in\ amps\ at\ H\ number\ n$

$I_{Peak} = Loading\ at\ maximium\ demand\ or\ Peak\ loading\ in\ A$

$n = H\ Number$

$R = Resistance$

$T = Total\ H\ in\ Period$

6.7 Cable System Bonding and Earthing

The submarine cable metallic sheaths shall be solidly bonded to earth at both cable ends by using suitable earth link boxes. All FO cables shall be terminated and earthed, when required, at transition joint bay (TJB) and offshore station points. All necessary power core and FO cable inter-sheath and sheath to earth bonding conductors shall be of insulated copper of adequate cross-section.

The sheath bonding arrangement shall be considered when establishing the current rating of the cable according to IEC 60287 and IEC 60853 for both steady state and dynamic rating approaches.

Earthing at the TJB point shall meet the following requirements:

a. EirGrid standard design shall be used to design the link boxes and Fibre chambers.

b. Link boxes at the transition joints shall be suitable for underground installation in the bay and shall 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.

Earthing at the offshore station shall meet the IEC 60529 requirements and the following additional requirements:

a. The sheath bonding and earthing scheme, including bonding leads shall be in accordance with Engineering Recommendation ENA-ER-C55.

b. 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 submarine cable power core screens.

c. Details for the connection of the link box to the offshore station earthing system shall be included in the cable system design.. (i.e., removable connection for testing purpose, minimum size of earthing conductors)

d. At offshore termination (GIS) end the FO shall be spliced at wall mounted kiosks.

6.8 Submarine Cable Construction and Material

The construction and materials required for the cables are as described below.

6.8.1 Conductor

The conductor shall be copper or aluminium. The conductor resistance shall meet the requirement of class 2 compiled with IEC 60228 latest publication. The cross-section area of the conductor shall comply with the current rating (calculated based on IEC 60287 and/or IEC 60853) in normal operation as well as short circuit failure conditions (calculated based on IEC 60949) in a fault situation according to system performance requirement defined in section 5.2 of this Specification. Water blocking components within conductor strands shall fulfil declared water penetration tested according to Cigré TB 490.

The Customer shall indicate the following details:

a. Conductor wire material information: material resistivity, enamelled or normal wire.

b. Number of wires and nominal diameter of wires.

c. Nominal outer diameter of conductor.

d. Number of segments (in Milliken type), if applicable.

e. Quality of copper or aluminium material.

f. Information of water blocking measures in conductor: water penetration depth, compliance of the material with conductor and conductor tape/conductor screen.

6.8.2 CONDUCTOR SCREEN

A conductor screen made of semi-conducting compounds shall be provided over the conductor by extrusion in the same operation as the insulation and insulation screen are applied to the cable. The extruded coat shall be continuous, with a constant mean depth, without bump, perfectly adhering to the insulation envelope. The semi-conducting polymer shall be cross-linked. The conductor screen average thickness and minimum thickness shall be stated in the Technical Schedules. The electric resistivity of the conductor screen shall as per IEC 62067 (clause 12.4.9.2).

A high penetration resistant semiconducting water blocking tape(s) shall be provided, with a minimum of 50% overlap, below the extruded semi-conducting conductor screen to prevent penetration of the compound into the underlying conductor.

6.8.3 INSULATION

The Insulation envelope shall be of cross-linked polyethylene (XLPE) insulation applied by triple extrusion. The extrusion method should give very smooth interface between semi-conducting screens and the insulation. Cross-linking shall be achieved using a dry-curing method.

The insulation layer shall be concentric with the conductor. The lowest measured thickness shall not fall below 90 % of the nominal thickness, as required in IEC 62067 (clause 10.6.2). All cable cores shall be thoroughly degassed prior to application of metal screen and core sheathing. Effectiveness of the degassing verification shall be performed in regular base, e.g., by-product component measurement on samples before and after degassing process.

The insulation shall withstand electrical, mechanical, and thermal stresses under normal and transient operating conditions. Mechanical property of insulation material shall fulfil requirement per IEC 62067 (clause 12.5.2).

For insulation degassing please refer to CIGRE TB 850.

6.8.4 INSULATION SCREEN

An insulation screen made of semi-conducting compounds shall be provided over the conductor by extrusion in the same operation as the conductor screen and insulation. Insulation screen shall be of non-strippable type. The extruded coat shall be continuous, with a constant mean depth, without bump, perfectly adhering to the insulation envelope.

The insulation screen average thickness and minimum thickness shall be stated in the Technical Schedules. The electric resistivity of the insulation screen shall as per IEC 62067 (clause 12.4.9.2).

6.8.5 Metallic Sheath

The metal sheath shall be of lead construction or welded metal sheath providing a radial water barrier. A foil laminate sheath is not acceptable. Thickness of the metallic sheath shall be homogenous, as per required by IEC 62067 (clause 10.7.1 and 10.7.2). If lead is chosen, the thickness of the sheath shall be minimized to reduce the losses.

A detailed calculation of the maximum short circuit current capability according to IEC 60949 shall be provided and shall meet the short circuit requirement in project specification. To meet the short circuit requirements of this specification, copper screen wires may, if required, be used in addition to the cable metallic sheath.

A high penetration resistant semiconducting water blocking tape(s) shall be provided under the metallic sheath to ensure the longitudinally water blocking the same specification as the conductor according to Cigré TB 490.

6.8.6 Core Over Sheath

The core over sheath shall be insulating or semi-conductive HDPE (ST_7 type) layer applied by extrusion. In case of insulating sheath, a semi-conductive PE layer shall be applied by extrusion or graphite coating. The surface resistivity of the PE layer shall be less than 16 kΩ/m length of cable, at ambient temperature. In case of semi-conductive PE sheath, the over sheath material should have the same non-electrical properties as for ST_7 type, except for the carbon black content.

Homogeneity of thickness of the core over sheath shall be according to requirement per IEC 2067 (clause 10.6.3).

Mechanical property of the over sheath shall fulfil requirement per IEC 62067 (clause 12.5.3).

There shall be embossed, or laser indented marking on the core over sheath, with phase number at every one-meter distance.

6.8.7 Integrated Fibre Optical Cables

The fibre optical (FO) unit layout and design shall be capable of monitoring cable temperature and cable strain for the entire length of the cable system as well as for the whole telecommunication purposes.

Minimum two fibre cables shall be integrated in the submarine cable.

Communication Fibre cables requirements described in this document do not account for Customer communication needs between the OSP and the Customer control room/control centre in the OCC or elsewhere. The Customer should calculate and design the additional number of pairs needed for their own communication requirements and consider these in addition to the number of optical cores required for the EirGrid systems.

Carbon Trust CTC 835 document and FOPA (Fibre Optic Cable Protection Assessment) recommendation shall be considered for the integrated fibre optic design and construction.

The expected lifetime of the fibre shall meet requirement in section 5.1 of this Specification. The design for the completed fibre connectivity shall in all aspects allow for any expected fibre creep whilst preventing the ingress of moisture, dirt or contaminants.

The optical fibres shall be single mode. A sufficient number of cores shall be included in the fibre cables for DTS and DAS purpose to enable sufficient and accurate conductor temperature measurements. Number of cores requirement, for DTS and DAS purpose, shall consider at least 2 additional fibres in the cable with 200 % redundancy within the cable.

For Station telecommunication purpose the integrated fibre cables shall, at minimum, match the land fibre cable specified in OFS-CAB-101 specification.

In consideration of the costs and project execution time to replace a faulty fibre cable the Customer shall ensure enough redundant optical cores are installed within the submarine cable. Fibre cable locations within the submarine cable, used and redundant optical cores, shall also consider the risks associated with external and internal mechanical pressures.

The FO cable shall contain single mode (SM) fibres (9 µm/125 µm) according to ITU-T G.652 and IEC 60793-2 standards. The optical fibres shall be comprised of high-grade silica with a UV cured double acrylate resin coating that shall be readily removable, for jointing purposes, by a non-chemical method without causing damage to the fibre core or creating a hazard to personnel. The marking of individual fibres, e.g., colour coding scheme shall be defined.

The FO loss shall be ≤ 0.35 dB/km at a wavelength of 1310 nm, at 1550 nm wavelength ≤ 0.22 dB/km and ≤0.24 dB/km at 1625 nm. The average splice loss shall be below 0.1 dB for each splice. The applicable standard is IEC 60793-1-40.

The mechanical properties of the fibres shall be defined with a proof stress level test (IEC 60793-1-30), stripping force (peak) test (IEC 60793-1-32), dynamic fatigue resistance aged and unaged (IEC 60793-1-33), and static fatigue, aged (IEC 60793-1-33)

Water-blocking shall be provided in the containment design according to CIGRE TB 490. Water blocking material shall be a proven material regarding long-term water blocking ability and regarding compatibility with the extruded cable layers. Water-blocking shall be tested, on an agreed Sample basis, using the test detailed in BS 7912 standard latest revision.

If the fibre design opts for installation of this cable in a stainless-steel tube, the Customer shall ensure that fibres are packed in loose welded stainless-steel tube to allow for the prescribed bending radius of the HV Cable. The ratio of HV cable length to effective fibre length shall be specified in the design, the method of overlay of the stainless-steel tube shall also be specified in the cable design.

Individual fibre cores shall be identified in accordance with Bellcore Standard EIA/TIA-598, UV colours shall not be permitted.

Where more than one containment tube is employed, the containment tubes shall be clearly marked using the ring-mark method with markings no less than 1 metre apart along the entire length of the tube. The Customer shall provide a diagram showing the arrangement and identification of multiple tubes in the cable construction.

The earthing of the metallic tube, when present, shall be in accordance with the earthing and bonding requirements in this specification.

The following optical properties shall be provided:

a. Chromatic dispersion coefficients, zero chromatic dispersion wavelength, zero dispersion slope (IEC 60793-1-42).
b. Mode field diameters at 1310 nm and 1550 nm, mode field concentricity error (IEC 60793-1-44).
c. Cable cut-off wavelength (IEC 60793-1-44).
d. Polarization mode dispersion (PMD) coefficient (IEC 60793-1-48).
e. Attenuation variation of fibres versus bending (IEC 60793-1-47).
f. Index of refraction (IEC 60793-1-22).
g. Cladding diameter, cladding non-circularity, core-cladding concentricity error (IEC 60793-1-20).
h. Primary coating diameter, primary coating-cladding concentricity error (IEC 60793-1-21).

6.8.8 Core Assembly and Armour Bedding

Laying-up of cable cores together with fillers and FO cables shall maintain an approximate round shape. The relative position of the power cores and FO cables should be controlled along the length of the cable. The Customer shall demonstrate how the position of the FO cables will be monitored / maintained during manufacturing and installation, to make sure FO cables not been damages by falling into lay-up core interstices or between armour wire strands.

The cable design shall incorporate filler and bedding materials which are non-biodegradable for the submarine cable service conditions outlined in this Specification. The use of yarn fillers, or equivalent materials that may allow migration under strain, to separate these components is not acceptable.

To minimise the risk of failures due to interaction between the power cores and the fibre optic elements of the cable, filler and armour bedding layer are recommended to be designed according to FOPA.

6.8.9 ARMOURING

Single, double or more layers of armour wires shall be applied over bedding layers on all cable designs.

The submarine power cable shall be armoured. A minimum of one layer of armour wires shall be included. It shall be possible to earth minimum two armour wires at both ends of the power cable. Armour wires shall be corrosion protected, e.g. galvanised in accordance with EN 10257. In addition the armour wires should be protected from corrosion by bitumen or similar.

Jointing of armour wires is not allowed in areas where the submarine power cable is subject to fatigue stress during operation. Where jointing of the armour wire is necessary they shall be welded and any surface irregularities removed. Welds shall be staggered and fully corrosion protected. Appropriate corrosion protection layer shall be applied on the armour layer.

6.8.10 OUTER SERVING

Polypropylene (PP) yarn is the preferred outer serving but other types may be considered as long as they are proven in service and type tested.

Outer serving should withstand the operating temperature and shall be compatible with any contacted cable material and the marine environment.

Thickness of extruded type outer serving should be big enough to withstand external mechanical forces.

6.8.11 MARKING

All Submarine cables with extruded over sheath shall be indelibly marked to ensure clear identification. Marking can be embossed, or laser indented with marking on each side, at 180 degrees, showing the following information:

- EIRGRID
- ELECTRIC CABLE
- 220000 Volts
- Manufacturer's name
- Cable type (XLPE)
- Year of manufacture
- Batch number
- Conductor size, number of core and material
- Anti-corrosion serving material type
- Cable distance / cable length every meter.

The embossed letters/figures shall be raised and consist of upright block characters with a minimum height of 10 mm. The gap between the end of one set of embossed characters and the beginning of another shall not be greater than 150 mm.

For PP yarn outer serving, each 100 m of the finished delivery length should be marked with durable, ROV readable and high mechanical strength markings.

6.9 Cable Accessories and Ancillary Components

6.9.1 General requirements

Cable joints and terminations shall have at least the same electrical strength as the cable itself.

Mechanical properties of accessories can deviate from those of the cable and should be specified.

The accessories shall have adequate structural capacity for their installation and cable pulling.

Cable accessories and ancillary components design and installation shall be done in accordance with Cigré TB 883, section 3.7.

6.9.2 Factory Joint

Use of factory joints is acceptable but shall be minimised, and the planned number of joints shall be specified and presented to EirGrid for review. If the length of the submarine cable is such that there is no alternative but to use planned factory joints, they shall be designed and tested in accordance with Cigré TB 490 and Cigré TB 623.

The installed location and phase allocation of all factory joints shall be clearly recorded.

The joint shall be flexible and able to withstand the same electrical, thermal and mechanical stresses as the power cores. Cadweld shall not be used for the conductor welds, unless proven to be the most appropriate solution by the Customer and agreed by EirGrid. Conductor screen material and insulation screen material shall be non-strippable. The insulation materials shall be of the same type and material as used in the power core manufacturing process. If not, the Customer shall document their solution with references, qualification testing and type testing for EirGrid approval.

Outer diameter of the factory joints shall be kept as small as possible to avoid any overall diameter increase in the factory joint area. If joints are required on multiple phases, the joints shall be installed in a staggered configuration. Splices shall be flexible type and the overall diameter shall be approximately equal to original cable in order to do not affect the continuous cable lay.

Unplanned factory joints should only be considered after a full route cause analysis and investigation with corrective actions has been undertaken and subsequently communicated to EirGrid. Splice location shall be identified with special marking on the outer serving.

Core splicing shall be performed prior to armouring and core splicing after that armouring is not acceptable.

Conduct either partial discharge test or X ray method on the section of the cable joints to confirm the integrity of the factory joints in accordance with CIGE TB 490 and results shall be submitted to EirGrid for review.

Jacket splices shall overlap the original extruded jacket material to retain the water tight integrity of the jacket.

6.9.3 Field Joint (repair joint)

Any repair joints due to incidents during manufacturing and load-out shall be investigated and the root cause analysis report shall be provided to EirGrid for review. Depending on the cause of the incident and the probability of reoccurring of the issue the cable may need to be replaced.

Repair joints might be unavoidable for offshore repairs. Submarine repair joints which minimise repair complexity and repair time are required. Details of the proposed repair joints and emergency repair proposal are to be provided to EirGrid with a full route cause analysis and investigation with corrective actions. Details to include the impact to submarine cable current carrying capacity due to the field joint.

The repair joint housing shall be as small in length and diameter as possible, but shall have the same strength as the cable itself.

Repair joints shall be designed and tested in accordance with Cigré TB 490, Cigré TB 623 and IEC 62067. Any special tooling requirements should be clearly stated. Consideration should be given to the armoured connection of the two cable sections. FO cables jointing box should be designed and tested together as an integrated part of the repair joint.

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.

Due to the limitation in installation vessel capacity or export cable length, field joint might need to be applied. The use of infield joint shall be minimised.

Repair procedure shall address remedial measures for potential damage scenarios during the course of the actual installation and post installation. It shall include both minor and major damages. This procedure should address the method to recover the submarine cable to surface for repair of the major damage in both deepest and shallowest water along the proposed route and shall include a catenary analysis. The procedure shall describe how the submarine cable will be laid back down on the seabed.

6.9.4 Termination (gas insulated switch gear)

The design of the termination kit shall be compatible with the selected power cable design, voltage requirements and switchgear design regarding selected standards, operational requirements, dimensions, and materials. It shall be done according to IEC62271-209 standard requirements.

The Customer shall ensure that the cable accessory manufacturer liaises with the supplier of the gas insulated switch gear (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.

In cable design, with insulated core over sheath, the termination design shall allow a DC test after termination which will be performed regularly during the cable lifetime. Dry type GIS termination are the only accepted type.

6.9.5 Sea/Land Transition joint (SLTJ)

The sea land transition joint shall be designed to interconnect the export land cable and the export submarine cable. Both will have extruded insulation but they will have design differences. The SLTJ will be installed in the jointing pit at landfall. The SLTJ shall be type tested for the project specific cables in accordance with IEC 62067. The SLTJ joint shall have the same or better mechanical properties as the land cable. The SLTJ joint shall accommodate the actual combination of materials and cross-sections included.

The location of the sea/land transition joint is determined by the landing topography and the thermal conditions, mostly for the submarine cable. The length of the submarine cable on land shall be minimised and the transition joint be located as close as possible to the shore. The following minimum conditions shall also be considered when selecting the transition JB location:

1) Flat area were straight sections of cable be obtained
2) Thermal conditions of the soil
3) Cable configurations
4) Ground conditions
5) Workspace requirements for pull-in and jointing operations
6) Access to the areas for construction, maintenance and repairs
7) Environmental constraints

The sea/land transition joints shall be designed and tested in accordance with Cigré TB 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.

Joint box of FO cables between submarine and land cable section shall be designed as part of the transition joint.

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.

The sea/land transition joints shall 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 submarine power cables and FO cables at the transition joint bay should be clearly stated on the design drawing.

6.9.6 Fibre Optic Splice Closure

The fibre splice closures shall be suitable for splicing of optical fibre cables as per required in this Specification. The increase in attenuation for each of the fibre splices in the installed splice closure as a result of operational strain shall not exceed 0.05 dB, measured at 1310 nm & 1550 nm.

The splice closures shall contain fibre organizer system where the extra length of fibres and splices are stored in systematic & secured manner.

The materials used for manufacturing the components/ parts of the splice closure shall be compatible with those used for manufacturing the cables in all respect and shall not affect the performance of the optical fibre cables and fibres.

The Customer shall provide all fibre optic splice enclosure and associated hardware and consumables required to complete and contain the fibre splicing at TJB and at the cable terminations ends. These components shall support the requirements set out in ITU-T Recommendation L.400 and be suitable for the intended HV Joint environment.

The Customer shall provide fully dimensioned drawings and detailed instructions describing the mounting of fibre joint closures, integration of fibres, dressing in raceways and sealing of entry ports. Enclosure shall be designed to fulfil the requirements of protection according to IEC 60529.

6.9.7 Link box

Cable link boxes must comply with the following requirements:

1) Link box chambers shall be provided to meet the requirements of the cable sheath earthing and connection design.
2) the cable link boxes must be large enough to accommodate clamp-on current transformers (CTs) for partial discharge monitoring.
3) Link box chamber locations shall be chosen where the terrain and access are suitable for facilitating the operation of cable sheath earthing and connection, maintenance, fault finding activities and future operation of the installation.
4) The cable link boxes must be lockable type, constructed from stainless steel (minimum grade 304) sheet metal panels.
5) The link box chamber at TJB shall be in close proximity to the Joint Bay so that the bonding leads connected to the joints will be no longer than 10m. The link boxes, associated lids and cable entries are to be designed and installed to prevent ground and surface water ingress in both rain and flood conditions.
6) Link boxes shall be designed to fulfil the requirements of protection according to IEC 60529

6.9.8 PULL-IN HEAD / CABLE GRIP (BULLHEAD)

The pull-in head or cable grip shall be designed according to DNV-ST-N001 Section 16 Lifting operations. Standard DNV-OS-H206 shall be applied for corresponding qualification and testing.

A pull-in head or cable grip shall be designed to withstand installation loads (including safety factors) without damage to the submarine cable or its functional components. The pull-in head shall be designed to withstand installation loads, such as:

- Tension during lay-down and pull-in (including increase in tension due to friction within the I- or J- tube)
- Bending over chute/laying wheel, entrance to I- or J-tube and within J-tube.

The pull-in head or cable grip shall be designed to allow uninterrupted travel over rollers/sheaves and through J-tubes and HDD without damage or snagging. The Customer shall specify the size relations between the guide tube internal diameter and the pull-in head.

A pulling head or cable grip shall be fitted to the leading end of the cable armour wires, through welding, moulding or clamping. The pulling head shall be completely watertight, with a full metal seal. The pulling head shall be capable of remaining watertight during cable pulling. The pulling eye arrangement shall be a design which facilitates sheath testing of the cable, without having to remove the heat shrink sealing, whilst onsite in the basket. This shall be achieved by connecting the metallic sheath or screen wires to the main conductor at the back of the pulling eye. The Customer shall ensure that the topside cable pigtail length above the hang-off flange is sufficient as required by the Design Basis.

A proof test shall be carried out at a load approved by the Customer and a certificate shall be issued.

6.9.9 HANG-OFF SYSTEM

The hang-off arrangement shall be used to secure the cable to the top of the guide tube or other securing location. The hang-off equipment shall be designed in accordance with DNV-OS-H102 to withstand the loads associated with the vessel motions and installation forces, and to transfer the loads without damaging the submarine cable or its components.

The hang-off shall generally consist of two systems: Temporary hang-off for quick assembly after pull-in and permanent hang-off terminated to the cable armour. The permanent hang-off shall be suitable for being bonded to the OSP structure.

The need for a seal between guide tube and hang-off collar shall be evaluated.

All mechanical loads shall be transferred from the armour to the support structure, for the design life of the cable system, without compromising the integrity of the cable.

The hang-off should be designed to provide the required level of sealing.

Anti-corrosion measures shall be applied to the hang-off system, to ensure operational lifetime of the hang-off system as defined in this Specification.

The hang-off shall be designed so to minimise maintenance requirements during the specified design life.

6.9.10 CABLE END CAPS

Submarine cable end caps shall be designed according to the specific requirement in projects: storage duration, installation water depth, able to withstand mechanical handling types (e.g., pulling tension with Chinese fingers applied on, etc.).

Customer shall provide testing report for the cable end caps that fulfil project requirements. Installation procedures of the end caps shall be provided by the Customer and strictly followed by the Installer.

7 CABLE ONLINE MONITORING SYSTEM

7.1 DISTRIBUTED TEMPERATURE SYSTEM (DTS)

A distributed temperature sensing system (DTS) shall be supplied with the submarine cable system with a 40-year design life. For DTS system requirement please refer to the EirGrid land cable functional specification “Distributed Temperature System” section, where applicable.

DTS system shall be designed and constructed according to the requirements in section 5.6 and 5.7 of EirGrid land cable functional specification and to CIGRE TB 756.

The DTS fibre of submarine cable will be spliced to the land cable DTS fibre at the TJB FO cable splicing closure and there will be a single DTS system monitoring the entire cable (end to end); therefore the two fibre have to be fully compatible with the overall DTS system.

The DTS system provides a monitoring capability using RTTR to dynamically rate the cable for both normal and emergency situations. The aim is to record if the designed operational temperature limit, outlined by the cable manufacturer, is exceeded during operation. If the designed operational temperature limit is exceeded, appropriate action will be required to bring the cable back within the required limits; depending on the cause of the exceedance, this may include but is not limited to remedial works.

7.2 DISTRIBUTED ACOUSTIC SENSING (DAS)

The Customer should propose a DAS system for EirGrid review to measure the strain on the submarine cable. The proposed system should work using a single mode fibre.

7.3 OPTICAL FIBRES CONNECTION

Optical fibres connectors of the FO cables shall be compatible with the DTS and DAS equipment as well as those used on a patch panel or splice enclosure.

In case pigtails are used in the connection, the fibre type used in the pigtails must also be the same as used for the field fibre and specified by the DTS or DAS equipment provider.

Optical fibres connection including pigtails must meet the requirements of IEC 61300 ‘Fibre optic interconnecting devices and passive components and IEC 60874-14 ‘Connectors for optical fibres and cables’.

8 Qualification Requirement

8.1 Pre-qualification (PQ) tests

8.1.1 General requirements for PQ tests

Pre-qualification testing on complete cable system shall be performed according to IEC 62067 and Cigré TB 490.

Range of PQ test approval shall be checked according to IEC 62067, clause 13.1.

8.1.2 PQ testing requirements

The prequalification test shall comprise the electrical tests on the complete cable system with approximately 100 m of full-sized cable, including at least one of each type of accessory involved in the project. The minimum length of free cable between accessories shall be 10 m. The tests requirements shall be as follows:

1) Determine test voltage values according to IEC 62067, clause 13.2.2
2) Test arrangement according to IEC 62067, clause 13.2.3
3) Heating cycle voltage test according to IEC 62067, clause 13.2.4
4) Lightning impulse voltage test according to IEC 62067, clause 13.2.5
5) Examination of the cable system according to IEC 62067, clause 13.2.6.

8.1.3 Extension of pre-qualification

When a prequalified cable system is changed by using another cable and/or accessory that is not part of a prequalified cable system or is already prequalified in another cable system with lower calculated nominal electrical stresses at the insulation screen of the subjected system, the pre-qualification test on this new complete cable system shall be performed by meeting all requirements in this section:

1) Electrical part of the tests on the complete cable system as specified in IEC 62067, clause 13.3.2
2) Non-electrical tests on the cable as specified in in IEC 62067, clause 12.5.

8.2 Type Tests

8.2.1 General requirement for type tests

All electrical and non-electrical type tests applicable to insulated cable system as specified in IEC 62067 or IEC 60840 and Cigré TB 490 shall be carried out if not previous type testing have been successfully performed covering the applicable cable system in accordance with the above mentioned standards. Previously performed type tests shall be documented with type test reports with a third-party approval. EirGrid will review the type test certificate, these can be considered applicable only if testing was performed on an identical or equivalent cable type.

Factory joints shall be type tested according to IEC 62067 and CIGRE recommendations, Technical Brochure 490 prior to start manufacturing, unless the joint has been type tested previously and documentation is provided and accepted by EirGrid.

Type testing shall be performed according to the above mentioned standards with the following clarifications/additions:

- All factory and repair joints shall be longitudinal and radial water penetration tested according to CIGRE TB 490;
- Electrical testing shall be done after the radial water penetration testing for joints;
- Single power core factory joints shall be additional tested as per below:
    - Conductor weld qualification including NDT (X-ray), tensile test and bending test (details to be agreed);
    - Hot set test according to IEC 62067.

The Customer shall submit a programme to EirGrid showing dates of all Type testing. The Customer shall submit the results of all type tests to EirGrid The type tests submitted must be those pertaining to the cable, fibre and accessories to be installed. All materials shall be tested to confirm the suitability of the supplier's design. Cable and accessories characteristics

Before the type testing starts, characteristics of cable and accessories to be used in the test shall be noted. IEC 62067 clauses 6 and 7 provide a list of these characterization descriptions.

During further developed qualification plan of cable systems or actual project productions, the range of approval of type testing programs must be checked according to the description in IEC 62067 clause 12.2.

8.2.2 Mechanical type tests

Mechanical tests are aimed to simulate the mechanical force that cable could experience during manufacturing, transportation, installation, in-service, or recovering processes. Subsea power cables shall be qualified by testing using appropriate mechanical loading which represents worst handling conditions, if not proven earlier with similar cable design. Testing shall be in accordance with Cigré TB 623. The following mechanical type tests are required:

a. Coiling test in case the cable has coil-able design, according to Cigré TB 623 clause 5.2.

b. Tensile bending test according to Cigré TB 623 clause 5.2. After the tensile bending test, the integrity of the FO cable shall be verified through a continuity check. Electrical resistance of the conductors should be measured both prior to the start of the test and after completion of the test and the value shall be within the requirements in IEC 60228.

c. Tensile test according to Cigré TB 623 clause 5.5 (e.g., no bending). If the expected maximum tension during installation (e.g., pull-in) or during the service life is higher than the tension used in the tensile bend test, a tensile test shall also be performed. If rigid joints are planned both as a field joints or repair joints, they must be subjected to tensile test.

8.2.3 ELECTRICAL TYPE TESTS

Electrical type testing shall be done after mechanical tests described in section 8.2.2 of this Specification. The test loop should comprise all types of accessories that are planned to be used in the actual projects. Ambient temperature of the testing loop shall be (20 ± 15) °C. A deviation from this temperature range should be agreed upon by the manufacturer and the Customer and may make sense in cold or hot water applications.

The testing loop shall have a U bend in accordance with the minimum bending radius specified by the manufacturer, or the bending radius specified in IEC 62067 clause 12.4.3, whichever is smaller.

The test shall be performed on one or more samples of complete cable, depending on the number of accessories involved, at least 10 m in length excluding the accessories (IEC 62067 clause 12.3). The minimum length of free cable between accessories shall be 5 m (excluding 0.5 m at the accessories).

Below electrical type tests programs are described:

1) Determine testing voltage values according to IEC 62067 clause 12.5.1
2) Partial discharge tests according to IEC 62067 clause 12.4.4
3) Tan δ measurement according to IEC 62067 clause 12.4.5
4) Heating cycle voltage test according to IEC 62067 clause 12.4.6
5) Switching impulse voltage test according to IEC 62067 clause 12.4.7.1
6) Lightning impulse voltage test followed by a power frequency voltage test according to IEC 62067 clause 12.1.7.2
7) Examination of cable and accessories according to IEC 62067 clause 12.4.8
8) Resistivity of semi-conducting screen shall be made on a separate cable and performed according to IEC 62067 clause 12.4.9.
9) The Customer shall also undertake to arrange for the short circuit test as a type test on any one size of the cable. Short Circuit test shall be witnessed by the purchaser's representative.

8.2.4 LONGITUDINAL/RADIAL WATER PENETRATION TEST

Before the water penetration testing, cable shall be subjected to mechanical testing described in chapter 8.2.2 of this document. Water penetration tests shall be performed according to requirements below:

1) Longitudinal water penetration test (LWP) on cables:
    a. Conductor LWP test, according to Cigré TB 490 clause 8.7.2
    b. Metal screen LWP test, according to Cigré TB 490 clause 8.7.3
2) Radial water penetration test (RWP) on joints:

a. RWP test of factory, repair, and field joints, according to Cigré TB 490 clause 8.7.4.

8.2.5 Non-electrical tests on cable components and on complete cable

Non-electrical tests shall be performed according to requirement below, with tests 2) to 9) shall be carried out on all cores:

1) Check of cable construction according to IEC 62067 clause 12.5.1
2) Tests for determining the mechanical properties of insulation before and after aging according to IEC 62067 clause 12.5.2
3) Tests for determining the mechanical properties of over sheaths before and after aging according to IEC 62067 clause 12.5.3
4) Aging tests on pieces of complete cable to check compatibility of materials according to IEC 62067 clause 12.5.4
5) Pressure testing at high temperature on over sheaths according to IEC 62067 clause 12.5.6
6) Hot set test for XLPE insulations according to IEC 62067 clause 12.5.10
7) Measurement of carbon black content for black PE over sheaths according to IEC 62067 clause 12.5.12
8) Test under fire conditions according to IEC 62067 clause 12.5.13
9) Tests on components of cables with a longitudinal applied metal tape or foil, bonded to the over sheath according to IEC 62067 clause 12.5.14.

8.3 Fibre Optic System Qualification Test

The FO cable system (fibres and accessories) shall have the same lifetime expectancies as the cables.

The product manufactured on representative production equipment should be tested for conformance to the requirements.

For system approval of the FO communication cable system, the test listed below are required. The number of fibres used for measurements shall be at least 10% of the total fibre count, rounded up.

8.3.1 Fibre qualification testing

The tests hereunder (non-exhaustive example) are performed on fibres. The test procedure and test method can be found in relevant IEC standards addressed below. The measured parameters should be in the range of limits that are according to the ITU-T G-series recommendations or test requirements should be agreed between employer and Customer.

1) Transmission characteristics:
    a. Attenuation coefficient- IEC 60793-1-40

   b. Chromatic dispersion- IEC 60793-1-42
   c. Cut-off wavelength- IEC 60793-1-44
   d. Macro bending loss- IEC 60793-1-47
   e. Polarization Mode Dispersion (PMD)- IEC 60793-1-48

2) Mechanical characteristics:
   a. Fibre proof test- IEC 60793-1-30
   b. Tensile strength- IEC 60793-1-31
   c. Coating strip-ability- IEC 60793-1-32
   d. Stress corrosion susceptibility- IEC 60793-1-33
   e. Fibre curl- IEC 60793-1-34

3) Fibre dimensions:
   a. Core diameter- IEC 60793-1-20
   b. Cladding diameter- IEC 60793-1-20
   c. Cladding non-circularity IEC 60793-1-20
   d. Core cladding concentricity error- IEC 60793-1-20
   e. Primary coating diameter- IEC 60793-1-21
   f. Primary coating non-circularity- IEC 60793-1-21
   g. Primary coating-cladding concentricity error- IEC 60793-1-21
   h. Fibre length- IEC 60793-1-22
   i. Mode field diameter- IEC 60793-1-45

4) Environmental characteristics:
   a. Damp heat- IEC 60793-1-50
   b. Dry heat- IEC 60793-1-51
   c. Temperature cycling- IEC 60793-1-52
   d. Water immersion- IEC 60793-1-53
   e. Change in optical transmission- IEC 60793-1-46
   f. Attenuation coefficient- IEC 60793-1-40.

8.3.2 FIBRE CABLE QUALIFICATION TESTING

The tests below (non-exhaustive example) are performed before integration of FO cable in submarine cables. The test procedure and test method can be found in relevant IEC standards addressed below. The measured parameters should be in the range of limits that are according to the ITU-T G-series recommendations or test requirements should be agreed between employer and Customer.

1) Mechanical characteristics:
    a. Tensile strength- IEC 60794-1-21 (Method E1)
    b. Abrasion performance- IEC 60794-1-21 (Method E2)
    c. Marking abrasion- IEC 60794-1-21 (Method E2b)
    d. Crush test- IEC 60794-1-21 (Method E3)
    e. Impact test- IEC 60794-1-21 (Method E4)
    f. Repeated bending- IEC 60794-1-21 (Method E6)
    g. Torsion- IEC 60794-1-21 (Method E7)
    h. Flexing- IEC 60794-1-21 (Method E8)
    i. Kink- IEC 60794-1-21 (Method E10)
    j. Tube kinking- IEC 60794-1-23 (Method G7)
    k. Bend- IEC 60794-1-21 (Method E11)
    l. Cut through- IEC 60794-1-21 (Method E12)
    m. Stiffness- IEC 60794-1-21 (Method E17)
    n. Bending under tension- IEC 60794-1-21 (Method E18)
    o. Coiling performance- IEC 60794-1-21 (Method E20)
    p. Diameter and thickness- IEC 60811-1-1
    q. Hydrostatic pressure- IEC 60794-1-22 (Method F10)
2) Electrical characteristics:
    a. Short circuit test- IEC 60794-1-22 (Method H1)
    b. Electrical continuity test on metallic parts- IEC 60794-1-22 (Method H3)
3) Environmental characteristics:
    a. Temperature cycling- IEC 60794-1-22 (Method F1)
    b. Water penetration- IEC 60794-1-22 (Method F5)
4) Cable Ageing- IEC 60794-1-22 (Method F9).

8.3.3 Fibre optic interconnecting systems testing

The connection of the cable monitoring system should be tested according to the requirement in IEC 61300 series and IEC 60874-14.

8.4 Other Project Specific Tests

Cable supplier shall provide evidence that the cable can withstand all expected mechanical loads during the production, transportation, storage and installation of the cable. These evidences will be reviewed by EirGrid. If required project specific mechanical test shall be performed according to Cigré TB 623:

a. Bending testing without tension,
b. Crush test,
c. Crush test for long term stacking,
d. Sidewall force test,
e. Impact test,
f. Pulling stocking test,
g. Handling force for rigid joint,
h. Sea trial,
i. Tensile characterisation test,
j. Friction coefficient test,

9 Manufacturing Requirement

9.1 Verification requirement

Production line for the actual project cables and accessories should be the same as what is declared as production line for cable system used in qualification and type testing programs. The process of product manufacture shall always ensure that sufficient and adequate quality checks are carried out to determine compliance of design and component material with established criteria.

Identification of production batch is important to trace back the failure cable length and production process and perform failure root cause analysis.The verification of required manufacturer service experience (refer to section 4.3) shall also be performed.

9.2 Quality control during manufacturing

Below quality control is required during manufacturing process:

a. Manufacturing plans shall be clarified before the starting of production, containing information: production location, machinery, personnel, production method, machine settings, degassing procedure, raw material suppliers, nonconformity handling, repair options, etc.
b. Hardware and the production line shall be certified, calibrated, and well maintained
c. Operational staff should be well trained and qualified for the responsible production process and it should be made sure they work with the correct workmanship

d. Manufacturing procedure shall be clear and strictly followed. The complete manufacturing process must be performed with sufficient and proper quality assurance and quality control. The Manufacturing process shall be documented precisely and in completeness for the purpose of back tracking in the future

e. Non-conformities during manufacturing process should be reported and handled in a pre-agreed way. Deviations from design and material criteria or any occurrence of manufacturing process deviation shall be notified to EirGrid.

f. The Customer shall submit a test program to EirGrid.

9.3 Routine, sample, and FAT tests

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

9.3.1 Routine test

To spot potential production abnormality, routine testing is performed on each manufactured component to check component meets specified requirements before they are assembled to final product. Routine tests are performed for every length and accessory supplied.

1) Routine tests on cable cores are required as follow:

   a. DC metal sheath/screen resistance measurement based on design requirement

   b. Partial discharge testing defined in IEC 62067 clause 9.2

   c. AC voltage test defined in IEC 62067 clause 9.3

   d. electrical test on over sheath of the cable defined in IEC 62067 clause 9.4, if required

2) Routine tests on accessories are required as follow:

   a. Test on main insulation of prefabricated accessories shall be done according to IEC 62067 clause 9.1

   b. Tests on factory joints shall be done according to Cigré TB 490 clause 6.4. Testing requirement on factory joints in this item over leads testing requirement IEC 62067 clause 9.1, whatever stricter

   c. Tests on repair joints shall be done according to Cigré TB 490 clause 6.6

   d. Tests on link boxes shall be done

3) Routine tests on FO cables are required as follow:

   a. DC voltage test of insulation for each manufactured length as defined in IEC 60229 clause 3.1, this test is applicable only for FO with insulated sheath. If the Customer opts for semi conductive FO sheath as per FOPA recommendation the Customer should propose a test to check the integrity of the FO sheath.

   b. An electrical continuity test of FO cable metallic elements, when present, should be performed as per IEC 60794-1-24 Method H3

c. Optical Time Domain Reflectometry (OTDR) for all fibres of each manufactured length and from both ends according to IEC 60793.

9.3.2 SAMPLE TEST ON CABLES

Sample testing on cables shall be done on regular frequency based on agreed quality control or based on frequency described in IEC 62067 clause 10.2. If the delivery length is up to 20 km, a length of cable sample 10-15 meter shall be taken and subjected to sample testing. If the delivery length is longer than 20 km, two tests shall be performed, with two lengths of cable samples taken from each end of the delivery length.

Sample tests on cables shall be carried out on each core of the samples and requirements are as below:

a. DC conductor resistance measurement according to IEC 60228

b. Conductor examination according to IEC 62067 clause 10.4

c. Measurement of electrical resistance of conductor and of metal sheath according to IEC 62067 clause 10.5

d. Measurement of thickness of insulation and core over sheath according to IEC 62067 clause 10.6

e. Measurement of thickness of metal sheath according to IEC 62067 clause 10.7

f. Measurement of core diameter according to IEC 62067 clause 10.8

g. Hot set on XLPE insulations according to IEC 62067 clause 10.9

h. Capacitance of individual cores according to IEC 62067 clause 10.10

i. Lightning impulse voltage test according to IEC 62067 clause 10.12

j. Test on components of cable with longitudinal applied tape to foil bonded to core over sheath according to IEC 62067 clause 10.14

k. Conductor water penetration test according to Cigré TB 490 clause 8.7.2

l. Metal sheath water penetration test according to Cigré TB 490 clause 8.7.3

m. Examine of complete cable according to Cigré TB 490 clause 7.1.16

9.3.3 SAMPLE TESTS ON ACCESSORIES

Sample testing on accessories shall be carried according to requirements below:

1) Tests on components according to IEC 62067 clause 11.1

2) Tests on complete accessory according to IEC 62067 clause 11.2.

3) Tests on factory joints according to Cigré TB 490 clause 7.2. Testing requirement on factory joints in this item over leads testing requirement in item b in section 8.3.2, whatever stricter.

9.3.4 SAMPLE TESTS ON FO CABLES

The testing standards adopted in the following items should be in line with the specifications set out in IEC 60794-1-2, as per the methods defined in various series of that standard:

1) Mechanical tests as defined in IEC 60794-1-21 (Method E):
    a. A non-destructive tensile test carried out on sample length > 50 m should be performed in accordance with the procedure outlined in Method E1
    b. The abrasion test resistance of the fibre optic cables should be performed in accordance with the procedure defined in Method E2
    c. A crush test should be performed in accordance with the procedure outlined in Method E3
    d. An impact test should be carried out on the fibre optic cable according to Method E4
    e. The strip-ability test of buffered optical fibres should be performed according to procedure as defined in Method E5
    f. The repeated bending test should be tested on fibre optic cable in accordance with the procedure outlined in Method E6
    g. The torsion test on fibre optic cable should be tested as per the procedure outlined in Method E7
    h. A bend test should be carried out as per Method E11
    i. The bending stiffness test should be carried out in accordance with the procedure outlined in Method E17
    j. The longitudinal and radial water penetration test as per IEC 6094-1-22 Method F5
    k. The underwater cable resistance to hydrostatic pressure as per IEC 60794-1-22 Method F10
2) Electrical tests as defined in IEC 60794-1-24 (Method H):
    a. A short circuit test should be conducted as per methods outlined in Method H1
    b. An electrical continuity test of cable metallic elements, when present, should be performed as per Method H3. This test is applicable only for FO with insulated sheath. If the Customer opted for semi conductive FO sheath as per FOPA recommendation the Customer should propose a test to check the integrity of the FO sheath

9.3.5 SAMPLE TESTS ON COMPLETE CABLE SYSTEM

In joint venture projects, sample testing on the complete cable system including all relevant accessories must be performed to proof the compliance of complete cable system.

9.3.6 FAT TEST

FAT is carried on the complete assembled delivery length including accessories (i.e., factory joints, if applicable). In case permanent mechanical equipment (e.g., hang-off heads) mounted on the cable before leaving the manufacturing site and accessories as part of the complete cable system delivery, the FAT shall be performed after the assembly of the whole cable system to be delivered. Acceptance criteria for each test shall be stated in the FAT procedure/plan. In case criteria is not met, the cause of the failure shall be investigated and reported.

The following FAT are required:

1) Cable system FAT testing:
    a. Cable DC conductor resistance measurement according to IEC 60228
    b. DC metal sheath/screen resistance measurement based on design requirement
    c. Capacitance of individual cores based on design requirement
    d. DC voltage test of core over sheath in case of insulating sheath material according to testing method described in IEC 60229 clause 3.1. This test is applicable only for FO with insulated sheath. If the Customer opted for semi conductive FO sheath as per FOPA recommendation the Customer should propose a test to check the integrity of the FO sheath.
    e. AC voltage test according to Cigré TB 490 clause 6.5.1
    f. Partial discharge testing according to Cigré TB 490 clause 6.5.2
    g. Time Domain Reflectometer (TDR) measurement
    h. A continuous Optical time-domain reflectometer (OTDR) measurements during load out from one end of the fibres
    i. Visual and dimensional inspection according to API 17E section 11.2. The cable shall be free from any damage, faults, or contamination
    j. Identification and marking of the cable and the identification and colour coding of the phase cables
    k. Cable load-out to be continuously video monitored with full visual inspection carried out for any signs of damage or anomaly. Alternatively, uni-directional OTDR (25% of the fibres) may be performed after completion of load-out onto the vessel. Deviations in the declared values and curves with respect to the ones measured during the FAT shall be reviewed.
2) FAT tests on cable link boxes must be submitted to EirGrid for review.

9.3.7 DTS TESTS

Post installation, and before commissioning, the DTS system shall be tested in accordance with general requirements of the Cigré TB 756:

a. Temperature Accuracy test

b. Temperature Resolution Test
c. Temperature Stability test
d. Step Response of the DTS system
e. Long term Temperature Stability Test
f. Functional Testing and Final Inspection
g. Spatial Resolution Testing.

Additionally, the following test results shall be carried out:

a. Environmental Testing (temperature stability and optical budget variation with varying instrument ambient conditions)
b. EMC testing of complete unit and individual components
c. CE conformance certification.

10 Cable Storage, Load-out, Transport, and Installation

10.1 Installation design philosophy

Requirements in Cigré TB 883 shall be considered for the submarine cables installation.

Relevant requirements for load out, transport and installation are given in Section 7 of DNVGL-ST-N001 Marine operations and marine warranty.

DNV's basic concept for design of marine operations is to ensure that the level of safety specified in relevant design codes is not jeopardised. This is achieved through careful planning of operations to ensure that the loads experienced are in line with the exceedance probability specified in the design codes. The overall objective is to ensure safety of personnel, equipment, and product. We have included the most important points to consider. More details are found in DNVGL-ST-N001 Marine operations and marine warranty.

10.1.1 Planning of installation operations

Offshore installations shall follow the requirements in latest version of OSCR-The Offshore Installations (Offshore Safety Directive) (Safety Case etc.) Regulations. In order to achieve the required level of safety, an installation operation shall be planned in such a manner that the product can be brought into a safe condition if the limiting weather conditions for the operation or sub-operation are exceeded. A safe condition is defined as a condition in which weather conditions in excess of the limiting weather conditions for an operation will not jeopardise the required level of safety for the product. A safe condition may be established by:

1) completing the operation
2) reversing the operation
3) abandoning the operation according to a safe and pre-planned contingency procedure, which should allow for a recovery of the object (e.g., cutting and lay-down of submarine cable), or

4) establishing a stand-by configuration that ensures that product integrity is maintained until normal

5) operations can be resumed.

Any limitations related to the product's properties (structural strength, size etc.), product components and/or installation equipment shall be considered in the planning of operations, both in relation to limiting weather conditions and contingency procedures, e.g., waiting on weather. Any such limitations shall be identified in the procedures. If relevant, the limitations in DNVGL-ST-N001 clause 2.6.8.2 should be considered.

All the equipment's, but not limited to, tensioner, cable counters, winches, load cell, carousal shall be calibrated and load tested and within its certification validity. Certificates shall be available on-board for inspection.

10.1.2 Installation Procedures

The cable installation procedures shall provide a full suite of documentation for the project and comprise manuals, specifications, method statements, procedures, drawings, calculations, records, certificates, and risk assessments, necessary to fully define the safe execution of the operations (DNVGL-ST-N001 clause 2.3.7).

Limiting weather conditions and maximum allowable duration of the planned operation, including any planned stand-by or contingency configuration, shall be specified along with applicable operational parameters to ensure that relevant limit state criteria are not exceeded.

Such procedure shall include but not limited to

1. Slow lay (to prevent damage to the submarine cable)
2. Barge heading change
3. Submarine cable abandonment and subsequent recovery

Operational procedures shall be supported by analysis to ensure that relevant limit state criteria are satisfied for weather conditions up to and including the limiting conditions for the operation and/or sub-operation. The uncertainty of predicted weather increases with the duration of the forecast, and this uncertainty shall be considered in the planning of operations DNVGL-ST-N001 clause 2.6.

10.1.3 Installation Engineering

Relevant limit state criteria defined in the recognised design code shall be checked applying the loads and/or load effects determined in the analyses and using the format applied in the recognised design code. Where the alpha factors in DNVGL-ST-N001 section 2.6 are to be used and unless steel work has been designed in accordance with the ASD/WSD requirements then the Load and Resistance Factor Design (LRFD) alpha factor may be used according to DNVGL-ST-N001 clause 2.6.12.1.

10.2 STORAGE

For storage requirement please refer to section 5.2.3 of EirGrid Onshore Cable Functional Specifications.

Requirements in Cigré TB 883 shall be considered for the storage of the submarine cables.

10.3 LOADING AND UNLOADING

Requirements in Cigré TB 883 shall be considered in the loading and unloading of the submarine cables.

Contractor shall provide all temporary work and equipment required for the load-out on the fabrication site, including cranes, tensioners, deflectors, rollers, guides etc.

A load-out procedure for the cable (and, if applicable, the cable protection system) shall be developed, considering all interfaces such as onshore/quayside conditions and transport/installation vessel conditions, refer to DNVGL-RP-0360 clause 5.3.2. The procedure shall also include ancillary components such as joints and terminations. The load out procedure shall include contingency for reversed spooling.

A detailed loading plan shall be produced well in advance of the loading campaign. Loading trials should confirm the suitability of the loading setup prior to loading of the actual cable.

Cable should be tested before being handed over. Manufacturer recommendations for the specific test to be performed should be followed.

10.3.1 LOAD-OUT MONITORING

Load-out operations shall be monitored.

Visual examinations should be conducted during and after loadout. The results should confirm that the cable has not been damaged during the operation. The loaded cable length shall be recorded.

The attenuation of the fibres shall be monitored at regular intervals, during the load-out operation using an OTDR. Should there be any change in attenuation or any apparent discontinuity in the fibre, the operation shall be stopped and an investigation shall be carried out. This test may be omitted if post-load out test is performed.

Tests after load-out, if any, should be specified.

10.4 TRANSPORTATION

Cable transportation shall refer to requirements in DNV-RP-0360, clause 5.3.3 and manufacturer recommendations.

10.5 CABLE INSTALLATION

10.5.1 PRE-LAY SURVEY AND ROUTE PREPARATION

Before cable installation, a pre-installation survey of the cable route should be performed, to determine and/or verify:

a. The present seabed conditions match those of the survey required in section 6.2.2 of this specification.

b. potential new/previously not identified hazards to the cable and the installation operations.

Survey shall be issued to EirGrid. Results of this survey should be reflected in the project execution plans.

10.5.2 CABLE ROUTE PREPARATION

Cable route clearance and cable route preparation should be carried out according to the specification developed during the design phase. If applicable, these works should be recorded and documented in a way adequate for as-built documentation.

Cable route clearance and cable route preparation activities should be carried out well in advance of cable lay and burial operations to accommodate for unexpected difficulties. Where unforeseen activities are required, a risk assessment should be conducted and submitted to EirGrid.

The Customer should consider the risk of presence of debris along the planned cable route. Depending on the result of a specific risk analysis a pre-lay grapnel run (PLGR) may be required, as near in time as practical prior to the cable laying operation to assure a debris-free cable route.

10.5.3 CABLE LAYING AND BURYING PROCESS

The Customer shall produce a cable laying plan detailing the pulling tension, lay angle and residual horizontal tension on the seabed that is required for safe installation, post-lay burial and minimising the risk for free spans. The cable installation procedure shall provide the operational limiting criteria for suspension and for restarting of installation operations.

During cable lay process following parameters shall be continuously monitored and controlled:

a. Vessel positioning and motion

b. Length of cable laid

c. Positioning of joints

d. Water depth

e. Top tension

f. Departure angle

g. Touch down point

h. Residual traction

i. Traction at sea level

j. Wind velocity and direction

k. Other information or events of importance during laying.

The cables shall be laid with minimum possible residual traction. The cables must not form a loop. The mechanical stresses on the cable in any moment shall be kept within the cable manufacturer's specified limits.

Continuous touch down monitoring shall be performed by ROV/ divers / by other means, Videos and coordinates shall be recorded and submitted the EirGrid.

Customer shall record the tension and angle exerted on the submarine cable during lay operations including any abandonment and recovery. The recording shall be continuous in nature by suitable automatic recording instrument. A copy of recording shall be submitted to EirGrid for the each cable laid in a format to be agreed with the Customer.

Any deviation from the expected behaviour of the cable during the installation as detailed in procedure / analysis shall be investigated and remedial action may have to be taken.

In case cable being buried in seabed, depending on the cable laying, and burying technology:

1) Where pre-lay trenching is performed:
    a. the required trench geometry should be defined
    b. it should be documented that the trench is stable
    c. the trench should be cleaned if excessive backfill develops prior to cable installation.
2) Where simultaneous lay and burial (SLB) is performed:
    a. cable catenary management should not be adversely affected by operation of the burial device
    b. direct feedback from the burial device should be used for positioning and heading of the cable installation vessel.
3) Where post lay burial (PLB) is performed:
    a. the trenching equipment shall be designed so that it does not violate the cable specification
    b. the laying of the cable should preferably be performed without divers
    c. cable tension in front of the trenching equipment should be understood / managed to avoid cable damage
    d. in beach areas, self-burial of the cable can occur, therefore the cable location may require recording/marking.

When the cable laying process must be interrupted due to bad weather, weather vanning, abandonment and recovery shall be planned and executed referring to requirements in DNVGL-RP-0360 clause 6.4.2.

Cable offshore jointing activities shall follow the requirements in DNVGL-RP-0360 clause 6.4.3.

An as-built survey according to DNVGL-RP-0360, covering the complete subsea cable system should be performed to verify that the completed installation work meets the specified requirements, and to document any deviations from the original design and if any remedial work is required.

The Customer shall provide a report certifying that the designed burial depth is achieved.

The as-built survey should be performed after work on the subsea cable system (or parts of a larger system) and its end points, including laying and burial, crossings, rock placement, artificial backfill, etc. are completed.

After laying, the documentation (including full video of laying campaigns) shall be worked out in an easily understandable way and in such a format that it will be easy to file.

10.5.4 Cable Pulling In

A cable pull-in analysis shall be performed, which includes:

1) Estimate maximum winch force required for the pull-in of the cable
2) For offshore platforms, find a snaking configuration where the CPS enters the J-tube bellmouth
3) with a small angle in the horizontal plane, less than 10° deviation from a straight entry
4) Determine the post-pulling-in configuration.

Consideration where to do first pull-in and second end pull-in shall be done. First end pull-in arrangement is normally done directly from the CLV into the landfall or offshore asset. The second end pull-in arrangement can be performed by cable laying in a surface bight (with floaters) or by cable laying on the seabed with or without help from a quadrant.

Project specific pull-in procedures shall be developed referring to guidance in DNVGL-RP-0360 and issued to EirGrid. The procedure shall be based on pull-in design and analysis incorporating dynamic amplification factors, supplemented by pull-in tests, as required.

Manufacturer shall give recommendation about how the cable shall be handled during pull-in activity, and the cable limit shall be respected during the handling process.

Once sufficient length has been pulled up the offshore unit, temporarily and permanent cable fixing components shall meet the requirements in section 10.6 of this Specification.

10.5.5 Repair of Cable After Installation Damage

In the event of suspected installation damage, damage shall be notified to EirGrid. An investigation of the cable incident should be performed before repair to establish the damage location and extent of damage and feasibility of the repair procedure. The Customer shall undertake the appropriate repairs.

After completion of the repair, a survey should be performed of the cable over a length sufficient to ensure that no further damage has occurred.

If the installation causes any defect that impairs the performance (optical or otherwise) of the fibre cable these shall be notified to EirGrid.

10.6 OFFSHORE ACCESSORIES/INTERFACE INSTALLATION

Cable installation at offshore station interface shall follow the requirements as below.

The requirements in DNVGL-ST-N001 clause 7.4.6, apply to all installation equipment for cable related marine operations. Requirements for specific installation equipment aboard vessels relevant to the particular method of installation are given in DNVGL-ST-N001 clause 7.4.7 to 7.4.13. Calibration and testing requirements are given in DNVGL-ST-N001 clause 7.4.13.1. Equipment used for operations involving cable shall be designed to prevent any relevant limit state(s) being exceeded.

Lifting equipment used to handle in-line and end structures/end terminations including pull-in frames and winches shall be designed in accordance with DNVGL-ST-N001 clause 16. The design of lifting equipment and lift points on such structures should be given special consideration to ensure that all possible load directions and distributions between different parts of the rigging are considered. Lifting and pulling points of A&R heads, lay-down heads and similar, shall be designed in accordance with DNVGL-ST-N001 clause 16, including the consequence factors (see clause 16.8.3). These shall be designed for the maximum dynamic tension expected and consider the worst possible load directions.

Use of hold back rigging (choked slings, Chinese fingers etc.) directly on the outer layer of flexible product shall be confirmed as acceptable by the product manufacturer. Similarly, the use of installation clamps should be confirmed acceptable by the product manufacturer and only be used according to their instructions.

Chinese fingers, cable grips etc. shall be suitable for the product including the load capacity and used in accordance with manufacturer’s requirements.

Where required, temporary product hang-off shall be well planned, using dedicated equipment only. The hang-off system should normally consist of well supported hang off collar/clamp. The equipment shall be suitable for the maximum design loads.

Electrical termination of the cable shall be done by well-trained certified jointers, strictly following the installation manual provided by manufacturer. Requirements in DNVGL-RP-0360 clause 6.9.1 may be followed.

10.7 LANDFALL CABLE INSTALLATION

For submarine cable installation in landfall section, for what applicable requirements should refer to “Cable installation” section of OFS-CAB-101 Underground Cable Functional Specification.

10.8 LAND-BASED SYSTEM INTERFACE INSTALLATION

The sea/land transition joint bay area shall be constructed in accordance with the design documentation.

When the necessary length of submarine cable has been pulled in, the cable shall be mechanically secured (anchored) in/at the sea/land transition joint bay.

The transition joint between submarine cable and land cable shall be jointed strictly according to the procedure provided by the joint manufacturer and approved by the cable manufactures. FO cable splicing and jointing should be included in the procedure.

After jointing process being fully completed, the transition joint bay should be closed and secured. Accessibility to the bay should be retained where feasible for the maintenance of the joints during the operational life.

The site needs to be restored after cable installation work being completed.

10.9 FIBRE OPTIC CABLE SYSTEM INSTALLATION REQUIREMENTS

FO cable system splicing, and installation shall follow the requirements in section 7.11 of OFS-CAB-101 Underground Cable Functional Specification where applicable.

The individual fibres of the fibre optic package shall be spliced in accordance with the specification at repair joints, offshore terminations, and transition joints.

Fibre splicing and FO cable enclosure jointing shall be done according to the installation requirement provided by the joint supplier and approved by the cable manufacturers.

Earthing bonding of the FO cable shall follow the installation procedure developed according to the requirements of section 6.7 of this Specification.

11 AS –BUILT PACKAGE

Customer shall provide As Built drawings that has been revised to show the post lay and remedial works, conditions including Material take off. The following documents shall be submitted to EirGrid for review:

1. As laid submarine coordinates including bearing minor bend coordinates survey data such as point of curve point of tangent, point of intersection, radius and other similar information. This data shall be plotted in the field chart in both PDF as well AutoCAD and submitted to EirGrid.

2. Actual length of cable installed, location and details of major obstructions, crossings, crossing supports.

3. Seabed contours related to LAT at 5 meter intervals.

4. Location of all nearby assets, cables, markers Location of splices or repairs in the cable.

5. Submarine cable pre and post installation test records.

6. Location of starts and stops of cable protection cover, trenching and other similar changes along the submarine cables include the depth from the top of submarine cable to natural seabed.

7. Location of spans and free span rectification supports (with pre rectification span length and post recertification span length)

8. Location, position and details of J tubes, bend restrictors, centralizer, cable ladder, supports, armour clamps, splitter box, terminations splices and other similar items.

9. Supply as built, video records for areas of submarine cable that are particular interest to EirGrid, at EirGrid request. Videos shall be colour and have a real time audio. Text shall be added to the video including the name of the cable, rated voltage, time and date name of the vessel location (UTM KS) along the submarine cable. The video record includes J tubes protective covers, starts and stop of the trenching, crossing and crossing supports areas of repaired damage and other similar items.

12 CABLE SYSTEM COMMISSIONING

Tests on new installations shall be carried out when the installation of the cable system has been fully completed. Commissioning tests is responsibility of the Customer and may be witnessed by EirGrid. As a result, adequate notice (> 2 weeks) of these tests should be provided to EirGrid to facilitate the witnessing of these tests.

A specific and detailed risk assessment and method statement shall be provided to EirGrid for review before these tests take place.

A commissioning report shall be submitted to EirGrid for review at the end of the commissioning phase.

12.1 CABLE COMMISSIONING

Cable Commissioning is Customer responsibility.

A Report shall be issued by the Customer to EirGrid at the end of the commissioning testing.

The following list of tests shall be carried out once the cable is fully pulled and jointed:

1) AC voltage test of the insulation defined in IEC 62067 section 16.3. This shall include a high voltage AC test using a resonant AC test system with PD monitoring. Cigré TB 841 provides guidance for after laying testing on cable systems using these new technologies. The Customer can consider the option to carry an AC HV PD test on the submarine cable and another to the Land Cable before they are jointed at the transition joint bay depending on the length of the two cables and availability of test equipment.
2) DC voltage test of the over sheath defined in IEC 62067 clause 16.2 if the cable design permits (i.e., if the outer sheath is insulating rather than semiconducting)
3) Time domain reflectometry (TDR) measurement on each conductor according to Cigré TB 490, clause 11.2
4) Measure Insulation resistance, phase to screen and phase to phase resistances
5) Check continuity of all phase and screen conductors
6) Check phasing of conductors
7) Check phase clearances and phase to earth clearances
8) Visual inspection of the connections in all link boxes to ensure compliance with the final design
9) Cable bonding diagram

10) Test the joint bays earth grids

11) A zero and positive sequence measurement

12) As laid resistance and reactance data shall be recorded.

12.2 FO CABLE AND DTS COMMISSIONING

The site acceptance tests for fibre optic monitoring systems are under development by Cigré WG 1.80 and related requirements shall be adapted once the TB is available. The following tests shall be undertaken as a minimum:

1) An electrical continuity test of FO cable metallic elements, where present, shall be performed as per IEC 60794-1-24 Method H3. This test is applicable only for FO with insulated sheath. If the Customer opted for semi conductive FO sheath as per FOPA recommendation the Customer should propose a test to check the integrity of the FO sheath

2) Optical Time Domain Reflectometry (OTDR) for all fibres of each manufactured length and from both ends according to IEC 60793. 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 Customer and agreed by EirGrid as part of the Customer commissioning test plan submission. The maximum loss at any point discontinuity shall be 0.1dB.

3) Tests on the Optical-electrical processing unit:

    a. Calibration of temperature measurement using a minimum of two temperatures

    b. Temperature resolution test

    c. Temperature accuracy test at maximum measurement range

    d. Scan rate test

    e. Sampling resolution test

    f. Spatial resolution test

    g. Test of on-screen alarm display

4) Tests on whole system: System resume after loss of AC power

5) Tests on data communication:

    a. Tests to confirm SCADA connection and data transfer

    b. Tests to confirm remote access including fault diagnosis.

13 Cable Operation and Maintenance

Cables and their accessories shall be designed so to minimise maintenance requirements during the expected asset lifetime. The Customer shall recommend a cycle for a visual inspection of the submarine cable system based on supplier/contractor's recommendations.

Standardised and interchangeable components shall be used for the scope of supply wherever the applications permit.

Components which are subject to replacement shall be interchangeable. The Contractor shall demonstrate this capability regarding the possibility to carry out these works offshore, tools necessary, personnel and training/knowledge required.

The Customer shall propose an asset management system for the cable system which complies with regulatory requirements according to DNVGL-RP-0360 clause 7.2.

The Customer shall propose an inspection plan, a business continuity plan and an emergency preparedness plan for the first proofing phase during which the Customer is responsible for the operation and maintenance of the cable system. The type of inspections and frequency must be adjusted to the local conditions and consider risk assessments, which could be based on the following.

- Offshore surveys according to Cigré TB 825, clause 5.1.2.1 and DNVGL-RP-0360 clause 7.3.2.
- Landfall inspection according to Cigré TB 825, clause 5.1.2.2
- Cable system inspection on platforms according to Cigré TB 825, clause 5.1.2.3.

13.1 Remedial work

13.1.1 Cable depth of Cover

A post burial survey shall be done to investigate whether the targeted burial depth has been achieved (refer to 10.5.3 for report requirement). Minimum depths of lowering for each section of the cable during its service life shall be derived from the design assumptions, CBRA methodology and the installation records. The thresholds for remedial work shall be defined. When thresholds are exceeded, appropriate mitigations shall be proposed and remedial works carried out.

Remedial work plan shall be prepared according to local conditions and circumstances and submitted to EirGrid.

Suitable methods may include:

a. Second Pass (post lay burial) with the same tool;
b. Second Pass (post lay burial) with different tool;
c. Rock placement;
d. Mattress or bag installation;
e. Concrete or PE piping;

f. Frond mattresses; and/or

g. Other means.

Results of remedial works should be surveyed and reported.

13.1.2 Free span rectification

No free spans are allowed. Free span rectification shall be required for location/condition:

a. All spans exceeding the specified acceptable length or height for the specific location.

b. Locations where scour or seabed settlement could enlarge the span length and gap height above maximum acceptable dimensions before the first planned.

Span rectification plan including methods of span rectification, protection regarding execution, monitoring and acceptance criteria shall be prepared submitted to EirGrid.

Requirements for vessels, survey equipment, etc. shall be addressed in the installation and testing specifications and procedures. The extent of procedures to be prepared and qualified shall be specified.

Adequate rectification of free spans shall be documented by a video survey.

13.2 Spares

The Customer shall consult EirGrid at an early stage to determine the requirements for cable spares. Processes and requirements are described in EirGrid OFS-GEN-009 specification.

13.2.1 Insurance Spares requirements

The scope of supply of spare parts shall be agreed with EirGrid, according to OFS-GEN-009 specification. The Customer shall supply the following spares at a minimum per cable. The Customer can recommend additional spares and different quantities and/or material of spare equipment.

Table 1. Cable and accessories minimum spares requirements.

Item	Quantity
Cable spare length for repairs (meter)	Minimum 500[1]
Repair Joint (piece)	4
Termination kits (piece)	6 (for each type used on the project)
Cable sealing kits (piece)	6 (for each type used on the project)

[1] The Customer shall conduct a project specific risk assessment to validate the spare cable length required for the entire route of the cable allows for two repairs.

Outer cover repair kit (for offshore repairs of cable outer cover) (piece)	2

In table above, 2 sets of repair activities are considered, 4 repair joints and 6 terminations in total are preliminary set here.

Customer shall assess the need to increase the spares holding over and above this based on the actual project characteristics, and the failure rate of 220kV submarine cables. Spare part sizing can be determined according to Cigré TB 825 if agreed with EirGrid.

Repair Joint means: Complete repair joints including bend stiffeners or bend restrictors applicable to any section of the cable (all cross-sections).

13.2.2 SPARE STORAGE AND PACKAGING

Spare cables storage should follow requirement in DNV-RP-0360, clause 5.3.1, Cigré TB 825, and cable manufacturer recommendations.

Spare cable storage method shall be as per OFS-GEN-009 specification and will be reviewed by EirGrid.

13.2.3 TRAINING

The Customer shall submit a training plan which shall describe in detail how the Customer proposes to train EirGrid staff for operation of future EirGrid assets.

Training requirements will be detailed further in OFS-GEN-009 - Operation and Maintenance General Specification.