Submarine Power Cable Systems
Design, Planning, and Implementation Guide

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SUBMARINE CABLE

BASIC METHODOLOGY

“How to plan & execute a successful submarine power cable project”
This Overview Guide is intended to provide:

- A broad overview of the specialized engineering and project considerations involved when including submarine cable in the design of a transmission system.

- Highlights of what is involved when preparing to develop or design projects involving submarine power cable installation with an emphasis on submarine cable laying & burial techniques.
Overview Objectives

- **Objective 1:** Identification of Project Needs; Project Design Parameters When Planning Submarine Cable Use

- **Objective 2:** Project Support Expectations When Designing and Developing Submarine Cable Projects

- **Objective 3:** A Discussion of Typical Submarine Cable System Sections, from Manufacture to Installation; Freighting, HDDs, Landings, Termination Structures, Planned Joints, and Submarine Cable Laying/Burial techniques.

- **Objective 4:** Typical Submarine Cable Project Commercial Structure and What to Expect When Preparing a Tender, RFI or RFP
Objective 1: Identification of Project Needs

- Project Needs: Design Parameters Warranting Submarine Cable Use
  - Is the cable route best served by a water body crossing, or is a water crossing unavoidable?
  - Very large lakes, rivers
  - Mainland to Island Systems
  - Inter Island Systems

- Offshore Wind Farms
  - Offshore Transmission
  - Bay crossings
  - Transmission or Distribution
Objective 1: Identification of Project Needs

- Customer Needs: Minimum Design Parameters to Move from “Concept” to RFI
  - Defining the minimum project parameters by the system owner in developing the initial RFI?

  - Power System Requirements
    - System Voltage, Nominal and Peak Current Expectations
    - Minimum Cable Design

  - System Depth of Burial Requirements
    - Help define anticipated ampacity calculations
    - Give a “first glimpse” of the possible installation methods

  - New Terminal Station vs. Existing Substation
    - Helps define logical site layout
    - Further defines anticipated cable routing plan

  - Conceptual Cable Route
    - Required at the earliest stages of permitting
    - Required to define both electrical and logistical parameters
Objective 1: Identification of Customer Needs

TYPICAL SUBMARINE CABLE TYPES OR CONFIGURATIONS

AC DESIGNS

- MVAC 3C XLPE
- HVAC 3C XLPE
- HVAC 1C XLPE

HVDC DESIGNS

- HVDC XLPE
- HVDC MI
Objective 1: Identification of Customer Needs

- What is the power design specification? Include fibers for SCADA, Coms, or DTS?
- 3-Core AC Cable
- Coilable Design??

![Submarine Power Cable Diagram](image)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductor Type</td>
<td>Copper 3C x 630sqmm</td>
</tr>
<tr>
<td>Insulation Type</td>
<td>XLPE</td>
</tr>
<tr>
<td>External Diameter</td>
<td>9.07 inches</td>
</tr>
<tr>
<td>Min. Bending Radius</td>
<td>181.1 inches</td>
</tr>
<tr>
<td>Max. Sidewall Pressure</td>
<td>2150 lbs / ft</td>
</tr>
<tr>
<td>Cable Weight (water)</td>
<td>36.9 lbs / ft</td>
</tr>
<tr>
<td>Cable Weight (air)</td>
<td>65.6 lbs / ft</td>
</tr>
<tr>
<td>Max. Pulling Tension</td>
<td>51808 lbs</td>
</tr>
</tbody>
</table>
Objective 1: Identification of Project Needs

- Single Core AC Cable
Objective 1: Identification of Project Needs

- Customer Needs: Minimum Design Parameters to Move from “Concept” to RFI
  - Defining the minimum project parameters by the system owner in developing the initial RFI?

DESK TOP STUDY

- Proposed Route
- Route Position List
- Cartography
- Bathymetry
- Geology
- Oceanography
- Meteorology
- Archeology

- Fishing Activities
- Restricted areas
- Permits required
- Existing utilities
- Cable Protection Survey
- Site Visits
- Survey Analysis
- Crossing Agreements
Objective 1: Identification of Project Needs

TYPICAL PERMIT CONDITIONS
- BOEM/USACE/State/Local
- Turbidity Control
- Water Quality
- Fauna/Flora Regulations
- Cable Corridor Restrictions
- Working Window Restrictions
- Pollution Controls
- Standard Care & Control
- Diligent EHS Control

PROJECT RISK ANALYSIS
- Work Site Safety – PPE
- Permit Receipt – Stipulations
- Equipment Failure/Damage - Contingency
- Severe Weather – Local Service
- Material Delivery – Logistics Control
- Regulator Interface
- Marine Traffic – Pre-Job Planning
Objective 1: Identification of Project Needs

Do We Have To Cross Any Existing Utilities??

NY Bight Existing Cables  Crossing Agreement?  Crossing Configuration?
Typical Example of an unburied pipeline crossing

Crossing Agreement to be negotiated with the Pipeline owner.
Typical Example of an unburied or buried cable crossing
Crossing Agreement to be negotiated with the Cable owner.

Objective 1: Identification of Project Needs
Objective 2: Project Support Expectations after Concept

• Project Support Expectations: Designing the Marine Route Survey

  • A submarine cable route survey is required very early in the development of the project..... long before the system plan can be finalized. The results of the marine route survey (MRS) will initially be required for the following (at a minimum:)

  • Probable USACE initial approval
  • ISO initial approval (where applicable)
  • BPU initial approval (where applicable)
  • Federal and State DEP initial permit applications
  • Archaeological and Historical Society review and acceptance
  • USCG planning
  • Vessel Traffic Control planning
  • Air traffic control planning (where applicable)
  • Ferry Authority planning (where applicable)
  • Presidential Permit approval for cross-border grid sharing projects
  • BOEM approval for wind-farms – SAP, COP, GAP, FDR & FIR
Objective 2: Project Support Expectations after Concept

• Project Support Expectations: Designing the Marine Route Survey

• The MRS data is then utilized by the marine installation contractors to ascertain general installation conditions and move the submarine cable route design closer to finalization.

The critical data used by both Permitting Agencies and the marine installation contractors when responding to a system RFI is as follows (at a minimum):

• **Side Scan Sonar Data**: Identifies avoidable surface targets and surficial existing utilities
• **Magnetometer Data**: identifies metallic obstruction and anomalous ferrous features; used in conjunction with SSS data, may allow for identification and verification of buried utilities
• **Sub Bottom Profile Data**: identifies geomorphology beneath the surface
• **Bathymetry Data**: Identifies depth contours along the submarine cable route
• **Grab Samples, Vibracore, and gravity core data**: Identifies seafloor/lakebed composition; penetrating methods identify both composition and KPa data.
Objective 2: Project Support Expectations after Concept

Marine Route Survey

Geophysical & Geotechnical Marine Route Survey

- Bathymetry
- Side Scan Sonar
- Sub-Bottom Profiler
- Magnetometer
- Burial Assessment Survey
- Thermal Resistivity
- Archaeological Survey
- Geotechnical Borings
- Finalize Cable Length
- Met-Ocean Data
Objective 2: Project Support Expectations after Concept

- Project Support Expectations: After the route survey
  - Permitting Support
  - Route Design Finalization (RPL)
  - RFI Coordination and response review support
  - RFQ Coordination and Documentation Generation
  - **System Design Finalization**
  - Vendor Review and Selection Support
  - Installation Monitoring, “11th hour” Engineering Support
  - Project Management, and Provision of Customer Representation at the Engineering Level
Objective 3: Understanding Submarine Project Sections

- The following “Parts and Pieces” commonly constitute the major tasks and sections of a submarine power cable system
  - HDDs / Open Cut Trench at the Landings
  - Pull-In configuration at the turbine
  - Termination at the turbine
  - Beach Manholes (BMH) and transition vaults
  - Terminal Stations, new or existing
  - Pothead Structures and Substation Interface Structures
  - Duct Bank to the Terminal
  - Land Cable Pulling
  - Cable Manufacturing and Factory Acceptance Testing
  - Cable Freighting to the Project Area
  - Cable Trans-spooling Operations and Testing
  - Jointing Operations
  - Submarine Cable Installation
  - Terminating & Commissioning
Objective 3: Understanding Submarine Project Sections

- HDDs / Open Cut Trench at the Landings

- Geo-Tech Bores?
Objective 3: Understanding Submarine Project Sections

- HDD configurations at the Landings are usually preferred by regulators
Objective 3: Understanding Submarine Project Sections

- HDDs / Open Cut Trench at the Landings
Objective 3: Understanding Submarine Project Sections

- Beach Manholes (BMH) and transition vaults
Objective 3: Understanding Submarine Project Sections

- Terminal Stations, new or existing
- Pothead Structures and Substation Interface Structures
Objective 3: Understanding Submarine Project Sections

- Cable Manufacturing and Testing
- Cable Freighting to the Project Area
Submarine cables will be freighted to US work area from a remote factory. Then trans-loaded onto the cable lay vessel prior to installation.
Objective 3: Understanding Submarine Project Sections

- Jointing & Termination Operations

Offshore Repair Joints

Transition Joints (Sea–Land)

Terminations (Indoor / Outdoor)

Link Box

 Armour Clamp
Submarine Cable Installation: Typical tasks addressed before barge operations

- Marine Route Survey
- Pre-Exposure Grapnel Run (PLGR)
- Route Clearance (RC) (abandoned utilities)
- Jet Sled Pre-pass (Pre-Rip)
- Rock and Overburden Removal
- Shore End Trench Preparation / HDD Installed and Pre-strung
- Separation Mattresses placed as agreed with 3rd party utility owners (all crossing agreements in place)
Objective 3: Understanding Submarine Project Sections

- Pre-Lay Route Preparation

- Pre Lay Grapnel Run (PLGR) & Route Clearance (RC)
Objective 3: Understanding Submarine Project Sections

- Submarine Cable Installation Methodology: Cable Lay Barges – Shallow Water

- Cable Lay Barges can be anchored (4-Point Moor) or use DP
Objective 3: Understanding Submarine Project Sections

- Submarine Cable Installation Methodology: Static Tank Vs Turntable (Carousel)

- Cable is Coilable? Coiling Test? Do we need a Turntable?
Objective 3: Understanding Submarine Project Sections

- Submarine Cable Installation Engineering: Marine Warranty Surveyor for WetCar Insurance Coverage
- Cable Weight & Volume Calculations For Barge Stability Check
Objective 3: Understanding Submarine Project Sections

- Submarine Cable Installation Methodology: Jet Plow Technology for Cable Burial

- Simultaneous Lay & Burial
Objective 3: Understanding Submarine Project Sections

- Submarine Cable Installation Methodology: Jet Plow Technology

Diagram showing the direction of plow movement as towed by barge, with labels for various components such as Cable from Barge, Cable Guides, Bell Mouth, Plow Blade, Plow Skid, Upper Pressure Chamber, High Volume Water Nozzles, Lower Pressure Chamber, and Cable Embedded in Seafloor.
Objective 3: Understanding Submarine Project Sections

- Simultaneous Lay & Burial Configuration from a DP Barge
Objective 3: Understanding Submarine Project Sections

- Submarine Cable Installation Methodology: Jet Plow Technology

**SUBMARINE CABLE PLOW**
- Adjustable Burial Depth
- Full Electronic Telemetry
- Video & Sonar
- Adjustable Water Flow
- Full Navigation Integration
- Tracked from Barge with USBL
Objective 3: Understanding Submarine Project Sections

- Submarine Cable Installation Methodology: Cable Lay Vessels or Cablesips for Deeper Water Operations.

- ROV or Trencher for Post Lay Burial Operations (PLBO)
Objective 3: Understanding Submarine Project Sections

- Submarine Cable Installation Methodology: Diver Burial
Submarine Cable Additional Protective Measures: Articulated Mattresses
Objective 3: Understanding Submarine Project Sections

- Submarine Cable Additional Protective Measures: Articulated Mattresses

**SPECIFICATIONS**
- **Mattress Type:** Construction
- **Mattress Dimensions:** 8" x 26" x 8"
- **Mattress Weight:** Air 15,500 pounds
- **Mattress Weight Submerged:** 6,000 pounds (approx.)
- **Concrete Density:** 145 lbs. per cu. ft., 4,500 psi
- **145 Elements:** 5/8" Ultra Violet Stabilized Copolymer Extruded Fiber Rope, Minimum Tensile Strength 9,500 pounds

**Total Hook Height with Mat = 20**
- **Frame Load Capacity (Weight of Mats) = 20.19 Tons**
- **Frame Empty Weight = 1 Ton**
- **Full Load Weight (Safe Working Load) = 31.16 Tons**
Objective 3: Understanding Submarine Project Sections

- **Post-Lay Testing and System Commissioning**
  - Phase Check, IR test & TDR Signature
  - Jacket Integrity Test for Underground Power Cable
  - Single End OTDR for FO Cable
  - AC Hi-POT and Partial Discharge testing
  - On site witness of 24hr soak test prior to in-service
• **Unique Commercial Structures / What to Expect**

  • Unlike other infrastructure projects, submarine cable manufacturers tend to act as the Prime Contractor for submarine cable projects.
    • Manufacturer’s Bonding Capacity tends to be the highest
    • Warranty Issues with the Submarine Cable when transferred to Installation Contractors for transport, handling, and installation operations
    • Component guarantees can be difficult to capture in the head contract Unless the Manufacturer directly carries this item

  • Utilities may prefer EPC Contracts over Design / Build Contracts to simplify their administrative commitment for large projects AND transfer some risk to a single sub scoped with a “turnkey” project plan.

  • Generally speaking, Engineering Companies should be approached VERY early in the project concept phase to act as the Owner’s Engineer for the entire project life.
Objective 4: Submarine Cable Project Commercial Structure

Typical Contracting/Supply Methodologies:

1. Furnish FOB Factory, 2. Furnish CIF Project Site, 3. Furnish & Install, 4. EPC

- Multi-Contract or EPC?
Typical Submarine Cable Task Breakout for a submarine cable project

1. Cable Manufacturer (Prime Contractor)
   - Design & Engineering for Power Cables
   - Supply of Power Cables with 2 FO units & Accessories
   - Supervision of Cable Laying
   - Jointing & Termination of Power Cables
   - Commissioning Test

2. Marine Installer (Sub Contractor)
   - Engineering for Submarine Cable Installation
   - Marine (Route) Survey and Clearance
   - Removal of existing cable & rock, if requested
   - Installation of Submarine Power Cable (Laying & Burial)

3. Underground Installer (Sub Contractor)
   - Installation of Underground Power & FO Cable
   - Support for Jointing & Termination of Power Cable
   - FO splicing work and Installation of cable support structure

**Not included in Contractor’s scope of work**

1) Environmental Permits
2) Substations, Manholes and Duct Banks
3) HDD works at landfall area (Optional)
1. Foundation
2. Wind Turbine Generator (WTG)
3. Nacelle
4. Inter-Turbine (Array) Submarine Cables
5. Offshore Sub-Station & Export Submarine Cable
6. On-Shore Grid Connection