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IEEE Guide for the Planning, Design, Installation, and Repair of Submarine Power Cable Systems

IEEE Power Engineering Society

Sponsored by the
Insulated Conductors Committee



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Abstract: This guide presents a list of factors to consider when planning, designing, installing, and repairing a submarine power cable.

Keywords: submarine cable, underwater cable

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Introduction

This introduction is not part of IEEE P1120-2004, IEEE Guide for the Planning, Design, Installation, and Repair of Submarine Power Cable Systems.

This guide has been prepared in the form of a list with brief explanations after each item. This list represents the more important aspects to consider when working on a submarine cable project. As such, this guide should be particularly helpful to the engineer who is occasionally presented with the challenge of working on a submarine cable project.

This approach is used because a comprehensive coverage of the wide variety of subjects involved in a submarine cable project would fill many volumes. Once this list has been used to evaluate a particular project, detailed information can be obtained by searching technical literature and by interviewing experts in the field.

This version of this guide addresses many more topics than the previous version. It also provides brief explanations of these topics to illustrate their relevance.

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IEEE Guide for the Planning, Design, Installation, and Repair of Submarine Power Cable Systems

1. Overview

1.1 Scope

This guide provides a list of factors to consider when planning, designing, permitting, installing, commissioning, and repairing submarine power cable systems. While many factors are common to both power and communication cables, this guide focuses on power cables that cross seas, lakes, and rivers.

1.2 Purpose

The purpose of this guide is to assist engineers in developing knowledge and to assure that important items are not overlooked when dealing with submarine cable systems.

1.3 Preface

Submarine cables are installed in unique environments using specialized installation techniques. Some uncommon characteristics that may be encountered include:

- A variety of environmental conditions, including the transitions between water and land
- Challenges in gathering geophysical information
- High installation and retrieval stresses on the cable
- A potentially hostile marine environment during construction and repair
- Human activities that do not normally threaten land cables

Even with these constraints, submarine cables have successfully served the industry since the 1890s. They sometimes offer a means of delivering energy and communications in a direct route that may provide superior system benefits and higher reliability, and sometimes they cost less than other alternatives.

This guide is broken into a number of clauses that roughly follow the milestones that a submarine cable project goes through. The milestones are commonly not sequential; for example, information will have to be gathered so the route can be evaluated, but one must have chosen a prospective route before a survey can be done.

2. Route selection

A number of factors must be considered when evaluating potential cable routes. Most of these factors influence the cost, constructability, reliability, and reparability of the proposed cable system, and they should be weighed along with the electrical benefits to the power system.

2.1 Natural marine conditions

Below is a list of naturally occurring marine conditions that may influence the evaluation of a prospective submarine cable route. Some of these conditions may vary considerably along the cable route, so an observation at one location may not represent the entire route.

2.1.1 Water depth

As the depth increases, cable-laying tensions will increase, which may influence the design of the cable and the installation method. Route surveys may also be more difficult.

2.1.2 Rock and pinnacles

Laying a cable over a sharp object may kink the cable. Where the cable is suspended between two points on the sea bottom, it may fatigue due to strumming (vortex-shedding vibration) induced by water currents. Where cable touches down, it may abrade on the bottom, especially if the bottom is hard.

2.1.3 Tidal, current, or surf action

Currents may carry silt or gravel that may abrade the cable. Strong tidal currents may wash the cable back and forth across the bottom, thus damaging it.

2.1.4 Shifting bottoms/scour

The soil under the cable may wash out, leaving the cable suspended and under high tension. Alternatively, the cable may become deeply buried (which will affect its ampacity and its ability to be retrieved).

2.1.5 Soil structural stability

The soil composition and consistency affect the stability of the walls of cable trenches. The presence of large boulders, rock outcroppings, and reefs can impede the trenching, plowing, and jetting operations.

2.1.6 Marine slope stability

Underwater landslides can damage a cable system.

2.1.7 Icebergs and pack ice

Icebergs being moved by the wind, river current, or tidal current can scour away soil and damage cables. Icebergs moving ashore can pound on cables in the subtidal and tidal zone.

2.1.8 Soil thermal properties

Soil thermal properties influence the cable design in terms of conductor size and operating temperature. Sediments with high amounts of organic material, oil contamination, or volcanic ash typically have high thermal resistivity. When cables are buried in soft mud by jetting, the sediment composition and its thermal properties may be altered.

2.1.9 Chemical attack/corrosion

Corrosive properties of some soils, or from gas emanation, may affect the cable design.

2.1.10 Sub-bottom material

The material below the surface may be entirely different than the surface material. Rock outcrops may lie just below the surface.

2.1.11 Very soft soils

If the bottom is very soft, the cables may continue to sink into the bottom after they are laid, causing them to be overstressed due to catenary tension. Excessive cable sinking also increases its external thermal resistance, and hence the operating conductor temperature.

2.1.12 Marine borers

Some marine organisms may burrow into the cable.

2.1.13 Storm action

Wave action from storms may result in beach erosion or filling.

2.2 Man-made obstacles

It is common to encounter manmade obstacles in the proposed submarine cable corridor, which may include:

- Other power, communication, submarine cables and petroleum pipelines. Joint installation projects, or integrating power and communications into the same cable, may reduce hazards.
- Pipelines, including sewer, water, and gas lines
- Effluent outfalls
- Sunken ships and debris, especially near docks and bridges
- Piers, docks, boat ramps, roadways, foundations, buildings, etc. These may be abandoned and not visible from the surface of the water.
- Disposal areas, either from dredging or dumping of refuse
- Restricted areas (for example, Naval training or testing areas)
- Future construction

2.3 Hazardous human activities

The most common cause of cable failure is mechanical damage by human activity. The damage may be caused by:

- Dragging anchors and tug boat lines
- Beached marine equipment
- Dock and bridge maintenance
- Dredging
- Dumped debris
- Fishing activity
- Shellfish harvesting
- Aquatic farming
- Pile driving
- Horizontal directional drilling
- Other cable or pipe laying operations
- Maintenance work on adjacent cables or pipelines
- Contamination of the seabed with chemicals, toxins, and heavy metals

2.4 Marine access

A number of factors may influence the desirability of certain routes, including:

- If the water is shallow for a long distance from shore, some marine craft and installation techniques may not be able to be used
- The distances the marine surveying vessels must travel
- The distance installation vessels must travel from dockage, the cable transfer port, and support facilities
- The distance to safe harbors for marine vessels for protection from inclement weather
- The size and length of the submarine cable, and the width of the cable corridor

2.5 Beach conditions

2.5.1 Slope and stability

Steep slopes may make the land portion of the route difficult to construct or unstable.

2.5.2 Beach composition

Poor digging conditions may make it difficult to lay the cable in the beach. Concrete cable chases, cast iron cable protectors, or other forms of protection may be required.

2.5.3 Access by land

It is beneficial to have access to beaches by shore-end marine installation equipment. It is desirable for the cable route from the water to the termination to allow for the cables to be installed and for the simultaneous passage of equipment and traffic.

2.6 Termination sites

The termination site may be as simple as a terminal pole, or a splice to a land cable, or as complex as a cable termination station that includes system protection, metering, transformation, and shunt reactors. The following is a brief list of factors to consider. See 6 for termination station design considerations.

- Access to beach landing of cable
- Equipment and water access to the termination site
- Proximity to power lines on land
- Access to station service power
- Proximity to communications lines or microwave tower sites
- Extent of site preparation
- Room for laydown area, site office, and temporary power
- Aesthetics/screening/landscaping
- Land use zoning
- Cost of land or right-of-way acquisition
- Future development

2.6.1 Elevation differences between terminations stations

When a fluid-filled cable system is used, it is desirable for the two termination stations to be at approximately the same elevation unless the fluid pressurizing will be done from one end only.

2.7 Installation considerations

2.7.1 Installation technique and environmental impacts

Alternative routes may go through various natural environments and different installation techniques may be required to install the cable in each environment. See 3 and 7 for more information.

2.7.2 Public access

Access to beaches, waterways, and boat ramps may be impacted by the installation operation.

2.7.3 Navigation

The cable-laying vessel may temporarily inhibit the free passage of marine traffic. This may require coordination with marine authorities, including local vessel traffic control, the Coast Guard, and the Navy.

2.7.4 Historical/archaeological significance

The preservation of historical or archeological sites may be required. Surveying or sifting through excavated material may be required to identify if archeological artifacts are present.

2.8 System integration

The submarine cable must be integrated into the existing systems on each side of the water. Some routes may provide more overall system benefit than others.

2.9 Length

In general, longer crossings are more expensive than shorter ones. An exception may occur if two route alternatives require different types of cable construction or installation techniques.

2.10 Width

The cable corridor width may vary with alternative cable system designs. For example, a single, three-conductor cable requires less right-of-way width than a system that uses four single-conductor cables (one cable being a spare). See 5 for more information.

2.11 Operating rights and permitting

Operating rights, including easements and leases, may be easier to acquire or less costly for certain routes.

2.12 Monitoring and environmental mitigation

Some routes may go through environmentally sensitive areas that will have to be monitored before and after the cable installation, and any damage may have to be repaired.

3. Permitting and environmental impacts

The route, installation method, termination station siting, and timing of the installation may all be influenced by the potential environmental impacts. Each route may have unique environmental aspects. Permitting agencies may require monitoring, mitigation, or compensation for any damage. In most countries, permitting agencies are located at the federal, state, and local levels. Aboriginal groups may also have jurisdiction. Some considerations are outlined in the following paragraphs.