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Crossing the Strait of Belle Isle

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ABSTRACT

The Strait of Belle Isle is the body of water separating the Northern Peninsula of Newfoundland and the Southeast Coast of Labrador. The Strait has a strong current dominantly along the Labrador coast line, this current is known carry several icebergs and pack ice from the North Atlantic to the Bay of Fundy. The strait has a maximum depth of roughly 100 meters, and the seafloor has little overburden and in other areas none, leaving only bedrock at the surface.

Newfoundland and Labrador are currently developing the Lower Churchill Project, which once finished will generate 2600 megawatts of hydroelectricity. The plan for this project is to transfer power to the island portion of the province to replace current out dated power generation plants. However, the main issue with transferring the power is crossing the Strait of Belle Isle. The Strait at its thinnest point is only 17 kilometres wide, but the harsh sea conditions and rough terrain of the Strait provide several obstacles.

In an effort to determine the best method of construction for an electrical conduit across the Strait of Belle Isle, research into previous conduit crossings projects was conducted. The main projects that were reviewed were the NorNed Project and the Kii Channel Project.

Utilizing the lessons learned from these case studies, the SOBI can determine the proper equipment, methods of protecting the cable, and appropriate risks.

1 INTRODUCTION

The Strait of Belle Isle (SOBI) runs between the Northern Peninsula of Newfoundland and the south east coast of Labrador is an area of rough terrain with harsh sea conditions, which makes it difficult in constructing a crossing for hydro electric power generated from the Lower Churchill Project.

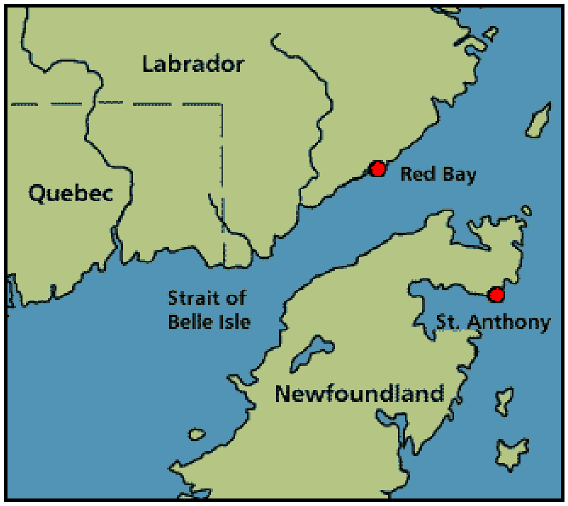

Figure 1: The Strait of Belle Isle
Image from www.heritage.nf.ca/exploration/basque.html

One of the primary methods to cross the strait would be to lay the cable along the seabed. This could take advantage on the natural terrain, but guaranteeing operational integrity could become difficult under existing conditions. The SOBI has a unique environment, ocean currents are strong and diverse, icebergs and pack ice could create several issues for the cables, and the seabed has low sediment overburden. Installation of the cable in the SOBI would require a vessel with positioning systems, turntables, feeder, and trenching or embedding equipment. The cables may have to be buried in the bedrock, and could require large volumes of rock placement in order to protect the cables from iceberg scour and vessel anchors. Since repairing cables after they have been laid and possibly buried is a costly endeavour, a major cost and risk analysis would have to be finalized and further analyzed prior to cable laying operations.

Due to the projects complexity it is integral to compare other cases to apply knowledge learned from previous projects. The NorNed Cable Project and Kii Channel Project were reviewed since their range of equipment, cables, and methods can potentially be utilized within the strait.

2 PROJECT OUTLINE

To construct an electrical conduit crossing across the Strait of Belle Isle to transmit power generated from the Lower Churchill Project to the island of Newfoundland. The crossing is an area of high concern and has been heavily investigated since 1973. Between 1973 and 1975 there were vertical boreholes drilled on both sides of the strait and their cores were the primary information used to outline the stratigraphy on both sides. This information was correlated along with Beaver Dredging Company's seabed cores from 1981 [1] to determine that the layers of strata slope from the Labrador coast to the Newfoundland coast. Since then several geotechnical investigations were conducted and figure xx shows the current bathymetry of the strait's seafloor.

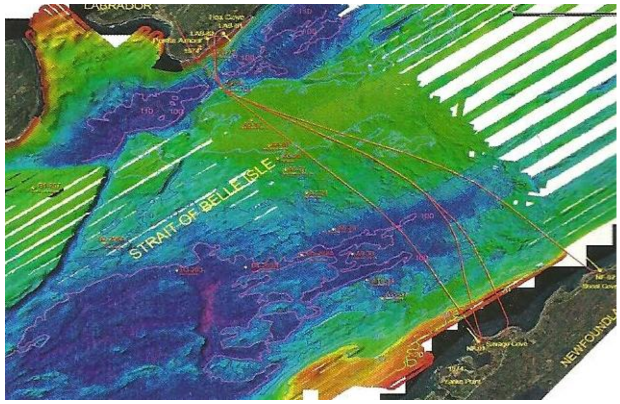

Figure 2: Strait of Belle Isle Seismic Bathymetry
Image from the Landsvirkjun Geotechnical Report [2]

Even with all the current geotechnical information to date, the SOBI marine crossing is extremely complex and poses numerous challenges for cable installation and protection. The bathymetry shows that icebergs have scoured a section of the seafloor along the Labrador coast. Also it is common during the winter and early spring months that the entire SOBI is covered in a thick layer of pack ice from the North Atlantic Ocean. These ice issues may worsen due to global warming breaking off larger amounts of ice than usual meaning bigger icebergs, deeper scours, and denser pack ice. Human activity does contain risks from anchors and fishing tackles penetration on the potential cable bed locations. These challenges pose different risks for the project that need to be allocated for when designing the conduit system.

3 CASE STUDY PROJECTS

Utilizing lessons learned from similar projects regarding their challenges and solution chosen will provide insight into designing the Strait of Belle Isle conduit crossing and where to allocate for risks.

3.1 NorNed Project

NorNed is the 576 km long HVdc submarine cable between Feda, Norway and Eemshaven, Netherlands, that connects the two countries electrical grids. The project cost was $740M to complete and is the longest submarine cable system in the world. NorNed was a joint venture project between the Norwegian transmission system operator, Statnett and its Dutch counterpart TenneT, who share costs and earnings on an equivalent ratio. The cable system has an overall voltage of 450 kV and a minimum capacity of 700 MW [3], which regulates both systems and allows for a more consistent electrical generation for both countries. The interconnection is setup for the market coupling, which causes the countries to trade one another's power when one country's grid has extra supply. NorNed transmits Norway's clean and relatively low priced hydro electricity to the Netherlands during the daytime, when the demand is high, as an alternative to the Dutch burning fossil fuels.

In late 2004, the ABB Group were given the contract for the NorNed project and began investigations of the surrounding area for possible routes and methods to lay the cable [4]. The Dutch engaged Primo Marine to carry out a burial study with their recommendations on how to properly protect the cables in the rough unstable conditions of the Waddenzee Sea. ABB used only mass impregnated (MI) HVdc cables with non-draining paper insulation. Two different cables were designed for the seabed portion of the project; a twin-core cable and a single core cable. The reason for the twin-core cable was that it prevents interference with ships compasses. Both types have copper conductors, a polyethylene jacket that protects the insulation from moisture and water penetration, and an outer layer of bitumen bounded polypropylene yarn that protects the cable from corrosion. The mechanical strength for the cables comes from the steel tape and two layers of steel wire armour which are applied in a counter helix design that eliminates tensional stresses. The cable was produced in six continuous lengths of 154 km of single core and 75 km of twin core [5]. The reason for using six sections of cable is to minimize jointing operations of the cables during the laying procedure, since no cable laying ship can cope with the total weight of the cables (over 35,000 tonnes). The types of MI cables used for the project have a total loss of 3.7% at a capacity of 600 MW at the distance of 576 km. The vessel chosen for the project was the C/S Nexans Skagerrak which has a 7000 tonne capacity and a 29m turntable.

Figure 3: Cross section of NorNed's twin-core cable
Image from www.kogl.dk

The cable route began with a 1.5 km section that was laid in trenches on land from the Eemshaven Converter Station, in the Netherlands, to the shore. At the shore the cable is connected to the twin core cable that runs for 270 km out from the Dutch coast and splits into two single core cables, which then goes into the deep section of the crossing, reaching a maximum depth of 410 m below the sea level, and continues straight on through the Feda Fjord. The cable then connects with the micro tunnel that is located 45 m below sea level off the Norwegian coast. The micro tunnel is 150 m long and was bored out by a micro Tunnel Boring Machine (TBM) using the pie jacking method. The cable connects to a jointing chamber which connects it to the MI cable running inside a 1.4 km long drill and blast tunnel, which then runs to the converter station in Feda. After the cable was laid it was trenched into the seabed by Nexen's Capjet remote operational vehicles (ROV's) and dynamic positioning equipment vessels. Near the Dutch coast the cable was buried to a depth of 3 m and only 1 m for the rest of the route. In areas where trenching was extremely difficult the cables were covered in layers of rock dumpings.

Commercial operation of the cable began May 5, 2008, with the first transfer the day after. Through the first two months of operation the cable produced $67 million in revenue, which covered 9% of the total project cost. In the projects business report it was only estimated to make $84 million annually. However, there have been two reported instances since operation [6]. First, in January 2010 the link was out of commission for four months when a cable failure occurred 70 km off the Dutch coast. The repair was complex and required ROV's to remove the failure section and to install the new cable, all during favourable sea conditions. Then, in April 2011 another cable failure occurred again ROV's had to excavate the failed cable, replace it and backfill the new cable section in.

The small energy loss over such a large span is good news for the Lower Churchill Project, also the concept of the micro tunnels to the seabed is a practical solution for the coast of Newfoundland and Labrador, and however the cable failures illustrate the difficulty and time consumption of a repair.

3.2 Kii Channel Project

The Kii Channel HVdc submarine cable project has a voltage of 500 kV and has one of the largest system capacities at 2800 MW [7]. Minato Works of Hitachi Cable manufactured four 48 km long oil-filled cables, with a 190 mm diameter and a rough weight of 100 kilogram per meter span. The cables transports electricity generated from coal-fired power plants on Shikoku Island to the Kansai region of Honshu Island. The cables design used a copper conductor with an inner oil passage. Next, the cable was insulated with polypropylene laminated paper and strengthened by a lead-alloy sheath. The cable was then lined with a polyethylene jacket and a layer of armour wiring [8].

Prior to any construction, Hitachi Cable conducted geotechnical investigations to analyze the channel's characteristics. First investigation was a field test that was carried out to interpret anchor penetration in different types of soil. Due to the Kii Channel having high sea traffic from fishing trawlers and tankers, the cables had to be deeply embedded for protection. Taking into account both anchor and fishing tackles dragged by trawlers, so the value of 3 meters in soft soil and 2 meters in hard soil were used. The next plan of action was to determine the cable route. Surveys were conducted to illustrate seabed geology, topography, and potential obstacles along the route. Sonar, using 3.5 kHz sound waves, showed that the thickness of the sediment along the route was usually more than 3 meters thick. Also, in the area that the sediment was thin, core samples were taken to evaluate if the ground was able to be trenched. Then an echo sounder and side-scan sonar were used to produce a topography map of the area, the seafloor was found to be relatively flat with several scattered boulders and maximum depth of 75 m. To clear potential obstacles away from the route a modern method was used to locate large obstacles, a large sensor array equipped with an acoustic positioning system. With the aid of a ROV to clear obstacles the array was successful in clearing the cable route [9].

Figure 4: Similar ROV used in the Kii Channel
Image from www.oceanexplorer.noaa.gov

Due to the short installation period the embedding machine and rock trencher had to be adjusted in order to keep up with the cable laying operations. A convectional embedder would have taken two weeks to bury the cable 2 to 3 meters deep across the channel. So, to improve production speed, a plough, consisting of six blades, and an embedder that used water jets was built. The new embedder used the water jets to liquidize the soil, reducing the towing force, and could bury the cable 3.3 meters deep and at a faster rate. A trencher had to be used where the cable had to pass through a rocky area, but a conventional dredger would lead to massive amounts of excavated rock and a lengthy construction period. Again, a new device was developed that shortened construction period and cost; a submarine rock trencher with a chain cutter able of cutting a .65 meter wide and 2.2 meter deep channel. Overall, with new technologies the project could run smoother and at a faster rate.

The laying operations began February of 1998, laying only one cable at a time during periods of calm weather and sea conditions. The cable laying vessel used for the project was the Giulo Verne. The Verne has a 19 meter turntable, capable of holding 7000 tonnes of cable, 490 kN of towing force, and an advanced dynamic positioning system. A portion of 5 km in the Tachibana Bay had to be laid by a barge due to the shallow water. As the cables were laid they were embedded or trenched simultaneously to reduce exposure. The operation took roughly two days to complete at a pace of 19.2 meters per minute (five times faster than conventional embedders).

The Kii Channel Project used extensive surveying and new technologies that allowed for a quick, accurate installation period, which maintained the projects short schedule. The submarine cable became fully operational in July of 2000, providing power to the Kansai region.

4 APPLICATION OF CASE STUDIES

The NorNed and the Kii Channel Projects both provide beneficial information regarding submarine cable conduits for their environments, but the importance are to determine what can be applied from each to the conditions at the Strait of Belle Isle.

First the SOBI task force at Nalcor Energy is currently reviewing the types of cables to be use, whether mass impregnated or oil filled, for the HVdc power transmission, as well as the various types of armour and protection. Similarly to the extensive geotechnical investigations for the Kii Channel, investigations were conducted throughout the strait that characterize physical environmental conditions that affect the proposed subsea cable installations. Bathymetry, seabed morphology, and seismic surveys were conducted in the 40 km by 50 km area, but mainly along the narrowest point of 17 km. Bathymetry shows a gradual dip of strata from the Newfoundland coast, but a sharper slope off the Labrador coast, and over the main corridor a gentle slope exists. The survey also showed two large marine banks that are separated by narrow channels that form potential pathways for the cables. Seismic surveys conducted illustrate that the seabed consist of glacial and marine sediments which overlay bedrock and typically do not exceed a five meter depth. Across most of the strait the seabed is comprised of coarse grained layer of pebbles, cobbles, and boulders, with areas of exposed bedrock that consists of sandstone, dolomite, limestone, and inter bedded strata of shale. Geotechnical data that Nalcor obtained are from trench tests and the soil borings done by Beaver Dredging in the early 1980's. The trench test was performed by a 5 tonne plough that penetrated the soil and rock in a range typically from 50 to 80 cm, with results showing that the seabed soils are thick and the bedrock has high strength, making trenching difficult. The soil borings had less than 5 m penetration, showing that the soil is compacted and has little overburden due to strong currents within the strait. The task force are also looking into applying micro tunnels similar to the ones used in the NorNed project to protect the cables near the coastal sections. Lastly, a study similar to the anchor and fishing tackle penetration study done in the Kii Channel should be conducted to determine if the SOBI is susceptible to tackle penetration.

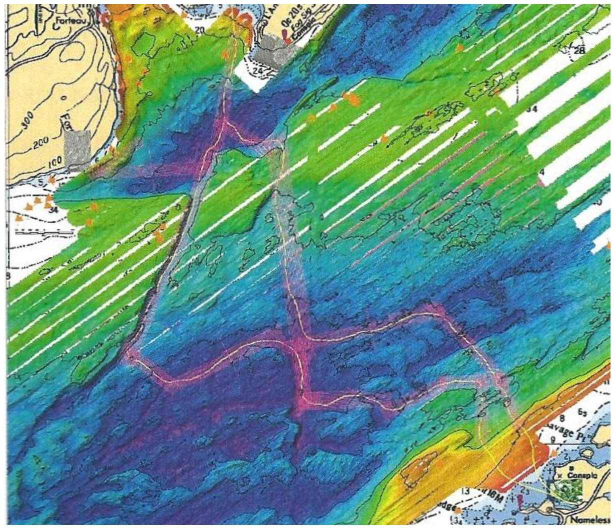

Figure 5: Potential conduit laying options
Image from the Landsirvjun Geotechnical Report [1]

However this project still has issues that neither project addresses, the main issue is regards to the iceberg scouring along the Labrador coast. Since no other submarine cable conduit had to deal with iceberg scours, extra precaution must be taken in order to prevent damages to the cable. Currently the plan is to use the natural trenches and ravines to protect the cables and then partially rock fill after the cable is securely placed.

5 CONCLUSION

The seabed option has similar projects in which reliable information can be leveraged for the development of the SOBI. The case studies provide information into cable protection methods, equipment, and types of cables that can be deployable in the SOBI. Through the study of anchor and fishing tackle penetration done for the Kii Channel Project, the SOBI can conduct their own penetration study, that should include iceberg scours, to calculate minimal burial depth of the cables. Both projects also show different methods in which to protect the cables that could be applicable to the SOBI, including rock trenching, cable embedding, rock dumping, and micro tunnels. In addition, the projects supplied some examples of cable laying vessels and types of HVdc cables that may be used in the SOBI. While also reminding of the complex task of replacing a cable once it fails.

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