8 Strait of Belle Isle Marine Cable Crossing

Report by: E. Colombo, Ing. (CESI)
A. Snyder, P. Eng.
P. Wilson, P. Eng.

8.1 Introduction

The Strait of Belle Isle (SOBI) cable crossing involves the placement of three submarine cables, 36 km long in a circuitous route across the Strait of Belle Isle. The cables will be installed from the landfalls on either shore beneath the sea bed using Horizontal Directional Drilling (HDD) techniques. The cables will then lay on the bottom in deep water, separated by a specified distance, and be protected by rock berms placed over top to provide the required cable protection. Given the directions provided by the numerous consultants' reports, a conceptual design has been developed to provide a technically feasible solution.

The cables will have a shore approach on the Labrador coast with a landing site in the area of L'Anse Amour beach in Forteau Bay and on the Newfoundland side in the area of Mistaken Cove.

The cable corridor in which the conceptual cable route is defined is shown in Table 21. The estimated shore-to-shore distance between Labrador and Newfoundland is approximately 18 km but the route chosen is a deep trough and has approximately 32 km of cable on the sea floor. The route is depicted within a 500 m wide corridor with a 1500 m diameter circular sea floor piercing target zone for the HDD.

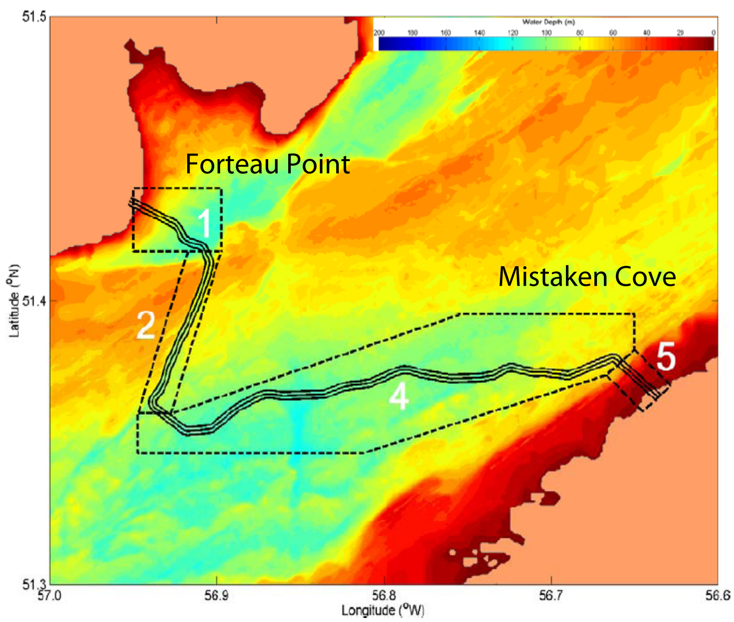

Figure 13: Strait of Belle Isle marine crossing route[171]

[171] Exhibit CE-44 Rev.2 (Public), Nalcor, "Strait of Belle Isle Marine Crossing 'Phase 2' Conceptual Design", May 2011

The SOBI marine crossing is extremely complex and poses numerous challenges for cable installation and protection. Challenges include sea currents, icebergs, pack ice, tidal forces, rock placement, varying water depths, fishing activities and vessel traffic.

To define cable protection requirements, the corridor was subdivided into the following zones:

Table 21: Marine Crossing Zone Definitions[172]

Zone	Features
1 - Labrador landfall	starts on land 150-1000 m from the shoreline and extends to a water depth of 65-85 m. Protection is required for tidal impacts, pack ice, icebergs, and fishing
2- Deepwater Channel	400-750 m wide; starts on the Labrador side up to the midpoint on the route. Protection is required for vessel traffic (dropped objects) and fishing
3 - Eastern Corridor	65-75 m water depth from the Labrador landfall to the Deepwater Basin. Protection is required for vessel traffic and fishing and iceberg scour
4 - Deepwater Basin	100-120 m depth from Deepwater Channel to the Newfoundland landfall. Protection is required for vessel traffic (dropped objects) and fishing
5 - Newfoundland Shore	about 10 km,16-85 m depth

8.1.1 HVdc Cables

The design envisages three (two load carrying plus one spare) single core conductor cables, each rated 450 MW at ±320 kV, with 150% continuous and 200% transient overload capabilities. The cables will have mass impregnated paper insulation, are double wire armoured in a counter-helical fashion to maximize pulling tension and provide rock armouring.

8.1.2 Fibre Optic Cable

Fibre optic cable will be constructed as an integral part of the conductor as opposed to a separate cable tied with straps to the pole cable.

8.1.3 Transition Compound and Terminations

At each side of the crossing, all three cables will terminate at a transition compound, to be designed, supplied, and constructed by the Engineering Procurement and Construction Management (EPCM)

[172] Exhibit CE-44 Rev.2 (Public), Nalcor, "Strait of Belle isle Marine Crossing 'Phase 2' Conceptual Design", May 2011

contractor. It is envisaged that the cables will be pulled to shore through the bore holes made by the HDD and then land trenched to the location of the transition compound. The compound location will likely be located 150 m to 1000 m inland from each shoreline. The compound will house the cable terminations, as well as any switchgear, insulators, and ancillary equipment that are required for system operation. Actual footprint and height of the compounds will be determined by the EPCM contractor and will be based on isolation requirements and installation techniques of the terminations.

8.1.4 Landfall - HDD

For both shore approaches, HDD will be utilized to protect the cables and will run from the shore to a point on the sea floor within the designated piercing target zone. This point is assumed to be approximately 1.25 km and 2.7 km from Forteau Point and Mistaken Cove, respectively (see Figure 14 having assumed a piercing depth of 80 meters).[173] The HDD solution will provide steel-lined boreholes for each shore approach.

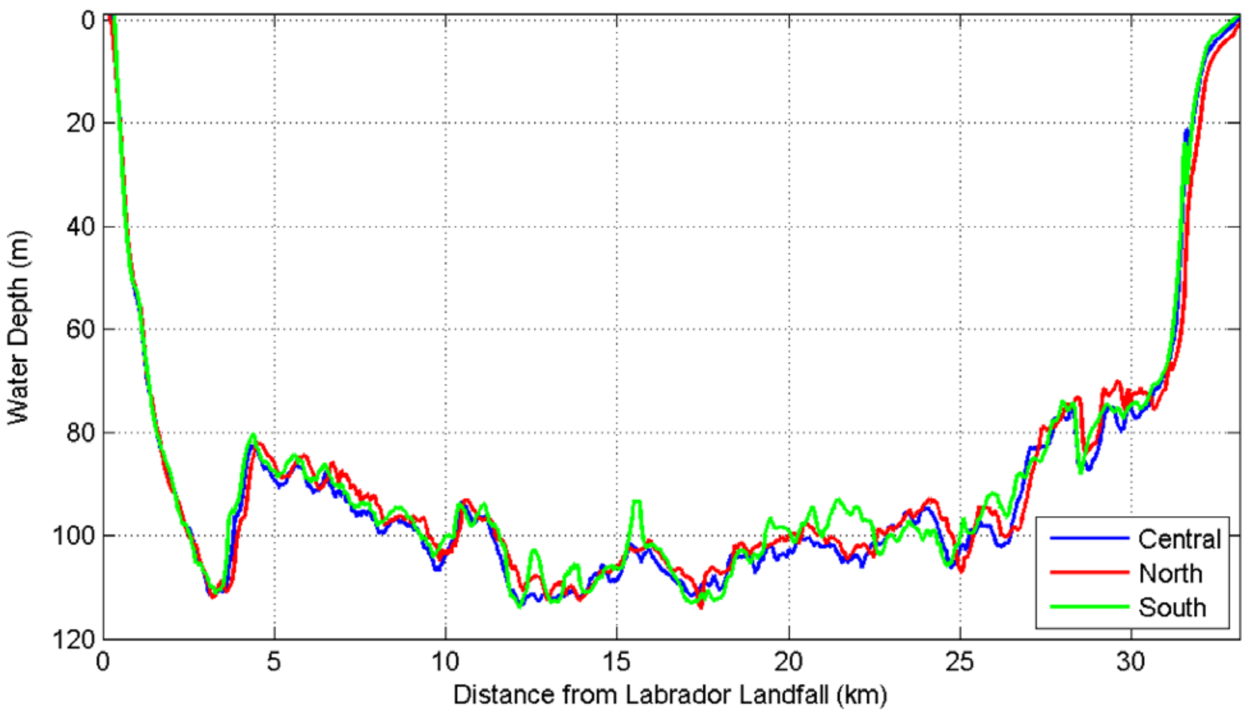

Figure 14: Water depth for the three cables of the link

8.1.5 Deepwater Zones – Rock Berms

For the deepwater zones, rock berms will be utilized to protect the cables both on the Newfoundland and Labrador sides of the Strait of Belle Isle.

[173] Exhibit 35, C-CORE, “Iceberg Risk to Subsea Cables in Strait of Belle Isle”, June 2011, pg. 178

Each cable will be protected by a dedicated rock berm; preliminary studies recommend that the rock berm will be 0.5 - 1.5 meters high, 8 -12 meters wide at the base and will have a side slope ratio of 1:4 (rise:run).

8.2 Scope of Review

CESI worked as part of the MHI team on this project reviewing key documents and reports which have been produced for this portion of the project. This review was to establish if the work was performed for Nalcor with the due care and diligence employing required practices and procedures normally completed in the performance of similar work.

Specific aspects of the documentation and reports were addressed for the verification such as:

- the existence of adequate and reliable source documents
- the accuracy and relevance of the inputs included in each report
- the methodology used to create each report
- the accuracy of the estimates or assumptions made in the existing analyses
- the presence of gaps or related issues in the existing studies, analyses and reports.

8.3 Approach to the Technical Assessment

In order to be acquainted with the context of the Strait of Belle Isle cable crossing project, CESI and MHI received and examined a significant number of reports released by Nalcor's consultants and met with one, C-CORE, to discuss their work on the project.

CESI is an Italian based consultant which provides services to utilities with respect to undersea cable technologies. CESI, as a subcontractor to MHI, reviewed documentation supplied by Nalcor Energy which they had used in arriving at their recommendation to develop the option for crossing the Strait of Belle Isle with three 450 MW, ±350 kV cables.

CESI commented on the reports, all of which are very recent and examined various options for the cable crossing. CESI generally agreed with Nalcor's selection of the preferred alternative which included HDD as a means of shore approach for the cable and laying the cable on the seabed with a rock berm protection scheme. CESI have made comments and recommendations related to the findings of the consultants and Nalcor's reports; these are noted in this report.

8.3.1 Boskalis 2010 Shore Approach Feasibility Study[174]

The Boskalis 2010 study reviewed the "technical feasibility of dredging and backfilling a shore approach for the HVdc cable crossing between Forteau Bay, Labrador and Mistaken Cove, Newfoundland."

The study focused on site conditions, work methods to be used, estimated volumes of material for three optional depths of trenches and various means of backfilling and protecting the cable.

The shore approach trenches would have been dredged, and cables laid in one trench, 0.5 meter apart. However further work was required to establish the heat transfer capability of the backfill material and once known, may have required three separate trenches which would have added substantially to the costs and may have required two work seasons to complete. Costs for this component of the overall project were very preliminary due to many unknowns at this point.

The report was based on a preliminary analysis of the site and a review of past studies conducted in the area. Significantly more investigation would have been required before a detailed design and more accurate cost estimate could be established. The proposed work methods and equipment to be used were in keeping with industry standards for this type of project. However much more would have to be known of the impact of ice, wave action and the underlying geological conditions. Due to risks to the cable of this type of shore approach, it was abandoned in favour of other options.

8.3.2 Hatch 2010 Feasibility Study of HDD for the Strait of Belle Isle[175]

The Hatch 2010 study reviewed the HDD method for construction of the shore approaches for the HVdc cable crossing. This technology has matured and allows for drilling on shore to a target zone on the seabed below which damage is unlikely to occur from icebergs or currents.

The Labrador side would require drilling approximately 1200 metres, whereas the Newfoundland side would require drilling approximately 2700 metres to a required ocean floor target zone, 80 metres below the water surface. These lengths of drilling are technically feasible, although the latter is approaching the limit of HDD technology. As stated in the report, risk assessments were completed for each crossing location, but the geological and installation risks should be evaluated and updated during design and before construction. The report goes on to state "the required casing pipe diameter, and subsequent bore diameter impacts the risk levels for this project." Costs of course will be dependent on the diameter of the bore hole.

The feasibility report adequately reflects the requirements for an HDD project of the planned magnitude. The geology of the two approaches has been studied but will require refinement before construction is undertaken. Previous reports did provide a good background and potential risks were documented. The cost estimates provided are reasonable for an HDD project of this scope but will also require refinement as more details become known. Risk mitigation measures were provided and a plan developed for a test pilot bore investigation.

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[174] Exhibit CE-40 Rev.2 (Public), Boskalis, "Shore Approach Feasibility Study – Strait of Belle Isle (SOBI) Cable Crossing", November 2010
[175] Exhibit CE-41 Rev.2 (Public), Hatch, "Feasibility Study of HDD for the Strait of Belle Isle", 2010

The HDD technology proposed would meet industry standards and thus is a technically feasible solution for the Strait of Belle Isle HVdc cable crossing.

8.3.3 Tideway 2011 Rock Berm Concept Development Study[176]

The Tideway 2011 Report has evaluated the rock berm concept as a means of protection for the submarine cables for the Strait of Belle Isle crossing.

The three HVdc cables are to be laid on the seabed when they emerge from the HDD bore holes some 80 meters below the water surface. The cables are planned to be protected to avoid iceberg damage, bottom fishing trawls, and ship's anchors. Tideway consultants have a standard they use for rock placement, rock sizes and rock stability to ensure stable and permanent protection. The water is as deep as 130 meters along the cable length but they concluded that rock dumping is feasible along the majority of the route. Larger rock is to be used in the shallow water (4 to 16 inches) and smaller rock (1 to 5 inches) in the deeper sections. They also reviewed two options for spacing – a nominal spacing of three metres between each cable and therefore one rock berm or cables spaced sufficiently apart so that the individual berms do not interact. The single berm is more cost effective but increases the risk of a single occurrence damaging all three cables.

The report has provided recommendations in keeping with sound rock berm construction practices. The assumptions concerning the logistics are conservative and their research of iceberg damage, naval vessels, that could be deployed, and method of rock placement was well documented. The rock sizes to be used in the berms and the planned thickness of the berms are in compliance with standards to protect the cable from the dangers described. Further detail design would be required when the decision is made to build one or three rock berms.

8.3.4 Tideway 2011 Shore Approach and Landfall Study[177]

This Tideway 2011 study reviewed three alternate means to bring the cables ashore both on the Labrador coast with a landing area in the vicinity of Forteau Bay and on the Newfoundland side in the area of Mistaken Cove. The Tideway study also recommended a trench excavation solution.

The Labrador side would require an excavation of approximately 750 metres in length to reach a water depth of 20 metres whereas the Newfoundland side would require 2300 metres of excavation to achieve protection for the cable. Tideway suggested that it would take two construction seasons to accomplish this work. They stated that "the burial requirement for the cable in the shore approach area depends on the potential impact of pack ice on the seabed and is expected to be between a minimum of 2m and a maximum of 4m." The study also stated that, "the most common landfall installation technique is an open excavation trench" with either a rock groin or cofferdam protecting the trench. They also discussed horizontal directional drilling as an option for shore landings. A third method evaluated was tunneling including new techniques of entering the ground on an angle. Tideway favoured open excavation as the most cost efficient methodology.

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[176] Exhibit CE-42 Rev.2 (Public), Tideway, "Lower Churchill Project Rock Berm Concept Development Study - Study Report", May 2011

[177] Exhibit CE-43 Rev.2 (Pubic), Tideway, "Lower Churchill Project Shore Approach Feasibility Study - Study Report", February 2011

It would appear that the proposed trench excavation solution was reasonable but there is a lack of detailed information and weather constraints do not appear to have been adequately addressed. Given the potential for weather and ice delays, the schedules may be inaccurate which may result in higher project costs. The 20 metre depth of water considered for cable burial near the shore may also be insufficient to avoid damage to the cable due to icebergs.

8.3.5 Nalcor's Strait of Belle Isle Marine Crossing "Phase 2" Conceptual Design 2011[178]

Nalcor used the information from previous studies to develop a technically feasible solution for extending the HVdc transmission system across the Strait of Belle Isle.

Nalcor selected a corridor with an estimated length of 36 km with approximately 32 km on the seabed. They selected a single core cable with or without an integrated fibre optic core with mass impregnated paper for insulation and double wire armour cover to maximize pulling tension and provide protection against rock cover. The cables would each be rated to carry 450 MW at ±320 kV. As stated in the report, all three cables would terminate at a transition compound located 150 metres to 1000 metres from each shoreline. For both shore approaches, HDD was selected to protect the cable and would run from the shore to a point on the seafloor in at least 80 meters of water. Cable installation would be in the steel-lined bore holes but will require at least one subsea joint. Rock berms would be deployed to protect the cables in deep water. A feasibility study execution plan was scheduled to be completed by year end 2011. A Westney Risk Assessment was also conducted and major risks identified. One of the major risks is the long lead times necessary to order cable and book the installation vessel.

CESI noted a concern about the lack of information regarding the cable laying vessels and the proposed plan for jointing and covering the joint area. It was thought that the quantity of mattresses proposed may be insufficient to cover the joints in the event of a repair. Also, a single layer mattress cover may not be adequate depending on the water depth and currents. There did not appear to be any consideration given to having a spare Remotely Operated Vehicle (ROV) on hand during cable installation as a breakdown of equipment could seriously delay the project.

8.3.6 Technical Note – Strategic Risk Analysis and Mitigation[179]

This document is being updated regularly by Nalcor and generally denotes areas where concerns should be addressed. While it is lacking details due to design being incomplete, the report would appear to be adequately covering all aspects of the project. Project schedules, construction tactics and mitigation actions have been documented. This report will be continuously reviewed and updated in advance of construction.

Nalcor indicated that they were in contact with suppliers to ensure that identifiable risk areas for the SOBI marine crossing were considered. Westney uses an interactive statistical process which is effective in both establishing risks as well as assessing the range of risk exposure.

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[178] Exhibit CE-44 Rev.2 (Public), Nalcor, "Strait of Belle Isle Marine Crossing 'Phase 2' Conceptual Design", May 2011
[179] Exhibit CE-52 Rev.1 (Public), Nalcor, "Technical Note : Strategic Risk Analysis and Mitigation", July 2010

There are no apparent gaps in the process at present but the project is in the early stages and a re-evaluation of risks should be undertaken at each decision point.

8.3.7 AMEC Report – Summary of Ocean Current Statistics – 2010[180]

AMEC reviewed and summarized available ocean current data for the SOBI crossing to produce estimates of the mean and maximum expected current speeds along the corridor route. They segmented the SOBI into "three horizontal sectors (north, center and south) and three depth levels (near surface, mid-depth and near bottom)". They also defined four distinct seasons as currents vary with each. Historic records were very sparse and did not represent a reasonable sample. Tidal conditions only represent a component of current speed but sufficient data is available to provide accurate estimates of dominant tidal constituents.

The consultants had very little data upon which to produce their findings. However the impacts of deviations from the norms would probably have little impact on the cable or the rock berm protecting it. Having a complete set of predictable data would make the task of establishing accurate current estimates easier. Having more information about mean and maximum currents near the seabed would be beneficial in establishing the rock berm size and shape necessary to protect the cables.

8.3.8 Canning & Pitt Associates Inc. Review of Fishing Equipment Report 2010[181]

Canning & Pitt prepared a baseline marine fisheries report in preparation for the Strait of Belle Isle Environmental Impact Statement. A number of methods have been investigated to protect the cable on the seabed portion of the line. The preferred choice of cable protection includes HDD for the shore portions and a rock berm covering the cables on the seabed. The scope of this study identified specific types of fishing gear and related equipment that may possibly come in contact with cables or the rock berm once installed. A five km area was studied on either side of the transmission corridor.

Scallops are the species most often fished in the area and the practice includes harvesting equipment which is towed over the seabed. Fishers in the area were contacted to provide information about the proposed cable corridor and allow them to ask questions about the possible impacts. It was established that no other fishing gear used commercially with the exception of purse seines posed any problems for the cables. Scallop dredges/rakes do present a potential threat to the proposed cable corridor and thus have to be controlled in the area. The only issue not highlighted in the report is the reaction of the fishers to the intrusion of the cables and rock berms in an area which had no interference previously. They have been consulted but additional consultations should continue to ensure that both parties have a clear understanding of what actions are required to ensure the fishery is permanently maintained. The cable route must be clearly identified so that interference is minimized. Fishers must be communicated with regularly as there have typically been claims for losses and compensation for habitat loss in similar circumstances globally.

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[180] Exhibit 33, AMEC, "Summary of Ocean Current statistics for the Cable Crossing at the Strait of Belle Isle", August 2010
[181] Exhibit 34, Canning & Pitt, "Review of Fishing Equipment – Strait of Belle Isle", December 2010

8.3.9 C-CORE and Fugro Geo Surveys Iceberg Risk to Subsea Cables in Strait of Belle Isle – 2011[182]

C-CORE and Fugro Geo Surveys conducted a review of the Strait of Belle Isle crossing as this area is frequented by icebergs which pose a hazard to any cables either placed on or trenched into the seabed. Their report described the application of a model to access iceberg risk to cables laid on the seabed in the Strait of Belle Isle.

The iceberg scour data was the first systematic assessment of the scour regime in this area. The report found that, "the observed spatial distribution of iceberg scours was unexpected with the majority of scours occurring in deeper water." However, these scours could have taken place in previous glacial periods. It must be noted that this cannot be positively confirmed and as such there is a risk generally in the 70 – 75 metre water depth range. The report stated that "the iceberg risk analysis used output from a Monte Carlo iceberg contact simulation that models the distribution of iceberg groundings and incidents where iceberg keels are close enough to contact a cable on the seabed." Icebergs have been observed to roll and this was considered in the simulations as an increased roll rate increases the risk to scouring. The report goes on to state that "the separation distance between cables was compared to observed scour length distributions and it was noted that the probability of contacting multiple cables is reduced with increased separation distance." The software used to model iceberg contact risks was developed by C-CORE and verified through other research on the Grand Banks, Conception Bay, and with field observations in the Strait of Belle Isle.

The Monte Carlo mathematical modelling techniques are well founded and provide a suitable estimate of iceberg strikes. The fact that this was the first ever study of the scouring potential of icebergs in the Strait of Belle Isle gives some cause for concern. Additional data sets and historical seabed investigations would have provided a higher degree of certainty in the simulation results.

8.3.10 Nalcor Energy Strait of Belle Isle Decision Recommendation – 12 October, 2010[183]

Nalcor Energy stated that two options for crossing the Strait of Belle Isle with the HVdc cables have been screened:

- *"Option 1 is the seabed crossing*
- *Option 2 is the tunnel or conduit crossing."*

Both options considered various technologies including the cables, installation, repair and maintenance, and protection.

Nalcor laid out conceptual designs for both options and then evaluated the risks of each, including monetary considerations. Nalcor has developed their own risk matrix with consideration to technical feasibility, safety, cost, schedule, contingency planning and geological complexity. There were five major risks associated with the tunneling option whereas the seabed option had none. HDD technology is advanced to the stage where it is practical to directionally drill and target an area for

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[182] Exhibit 35, C-Core, "Iceberg Risk to Subsea Cables in the Strait of Belle Isle", June 2011
[183] Exhibit 37, Nalcor, "SOBI Decision Recommendation", October 2010

egress at least 80 meters below the water surface reducing the risk of strikes. Thus the seabed option was recommended to be carried forward to the Environmental Assessment and detailed design stage.

Nalcor's recommendation on the Strait of Belle Isle marine crossing is a good synthesis of the conclusions of source documents, and represents a sound decision-making process. Detailed design will lead to more accurate cost estimates but those represented for this stage, can be considered realistic and conservative. It is also assumed that the schedules and cost estimates for the marine operation are inclusive of weather contingencies and a reasonable allowance for equipment downtime.

Since Nalcor's review is based on other documents, its accuracy and completeness is dependent upon those attributes and completeness in preceding documents. Having reviewed those reports, it is agreed that their recommendations are well founded.

8.3.11 Nalcor Energy Request for Proposal for Strait of Belle Isle Submarine Cable Design, Supply and Install – August 2011[184]

Nalcor's request for proposal (RFP) for the Strait of Belle Isle submarine cables was issued in August, 2011 and reviewed by CESI. The document describes the scope of work and asks for a preliminary execution plan to establish the proponents approach, commitment, and ability to carry out the work. The general specifications and requirements are in line with industry standards, including the materials and equipment to be used on the project.

8.4 Cable Risks Assessment

The Confidential Exhibit CE-52 which describes the Strait of Belle Isle cable crossing as an engineering/technical risk was reviewed by CESI and MHI. Nalcor developed strategies to mitigate the identified risks which brought the potential impacts down to a reasonable range. Such mitigation included additional feasibility studies on shore approach and iceberg risk, utilizing a spare cable, appropriate cable protection methods, along with the selection of a more mature and proven MI cable technology. Even with the actions taken to reduce risk, there is still a risk of cable failure during operation. This section quantifies the likelihood of a failure, and highlights industry recommendations to mitigate failure.[185]

Cable failure rates based on historical performance data are required to estimate the impacts, severity, and consequences of a cable failure. Review of available literature, in-depth review and technical knowledge of the application, and data from suppliers will allow Nalcor to design an appropriate cable protection system.

Both land and submarine cable failures do occur and are quantifiable. However, the difficulty is that good historical information is not readily available.

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[184] Exhibit CE-55 Rev.1 (Public), Nalcor, "Request for Proposal (RFP) No. LC-SB-003 Strait of Belle Isle Cable Design, Supply, and Install", August 2011

[185] CE-52 Rev.1 (Public), Nalcor, "Strategic Risk Analysis and Mitigation"

Two key documents used are:

- Cigré TB 379, "Update of Service Experience of HV Underground and Cable Systems", April 2009. Working Group B1.10

  Cigré WG B1.10 study was undertaken to collect and analyse data relating to the installed quantities of underground and submarine cable systems rated at 60 kV and above. More than 33,000 circuit km of underground (land) cables and approximately 7000 circuit km of submarine cable systems were identified as being in service at the end of 2005. The data collected is representative of the reliability performance based on trends in technology, design and service experience.

- Cigré TB 398, "Third-Party Damage to Underground and Submarine Cables", December 2009, Working Group B1.21.

  Failure statistics show that the risk of third-party mechanical damage is three to five times higher than the risk of internal failures for cable systems. Methods on how to reduce the number of damage events to the cables are discussed in Technical Brochure 398.

  To determine methods to reduce the number of failures caused by third-party damage, a survey was conducted by Cigré Working Group B1.21. The objective of this study was to investigate possible ways of reducing the risks of third-party damage. The Technical Brochure discusses the results of this survey and takes into account the failure statistics from TB 379.

8.4.1 Reliability Predictions

In April 2009, Cigré Working Group B1.10 completed TB 379 "Update of Service Experience of HV Underground and Cable Systems". It compiled the results of a power utility survey completed in December 2005. Results of the survey showed a trend continuing toward application of XLPE ac cables to replace self-contained fluid-filled (SCFF) ac cables, spreading to the highest voltages, i.e. 500 kV. Unfortunately there was very little data on the performance of HV cables in the range of 220 – 500 kV. For dc applications, the survey showed MI cables continuing to dominate, but with XLPE cables used more frequently up to 150 kV.

The TB 379 survey data reported that internal failure probabilities are zero for MI dc submarine cables[186]. There is an acknowledgement, however, that some of the failures reported as 'other', could have been internal. Of course a zero failure rate is unrealistic because it would infer infinite cable life, whereas it is commonly accepted that cable systems have a design life of 40 to 50 years under normal loading and maintenance conditions.

Table 30 in TB 379 also indicates that the Failure Rate for causes External and Unknown is 0.0998 failures / 100 km-yr. There are a total of 18 events[187] that define cable failures for this class of cable (MI dc). External causes (11 events) include cable damage as a result of a third party mechanical

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[186] Cigré TB 379, "Update of Service Experience of HV Underground and Cable Systems", April 2009. Working Group B1.10, Table 30

[187] Cigré TB 379, "Update of Service Experience of HV Underground and Cable Systems", April 2009. Working Group B1.10, Table 28

damage such as an anchor, or fishing trawler, or excavation activities. Other causes (five events) were defined as physical external influences which may include subsidence, or abnormal external system conditions (i.e. lightning). Unknown causes account for only two events.

Since there is no dependable and statistically significant data base on submarine cable failure statistics for internal failures (Internal failures are defined as insulation breakdown, manufacturing defects, or improper installation), this does not infer that Nalcor should not expect submarine cable failures. For example, the authors are aware of the following apparent internal submarine cable failures that have occurred within the last decade[188]:

2003, England – France 270 kV HVdc cable:

- A fault 4 km from UK at a 20 m depth. Buried cable was found twisted and failed after 17 years of service, apparently due to initial installation difficulties.

2004, New Zealand 350 kV HVdc cable:

- One of the three buried cables had a fault at 150 m away from the North Island landing point, apparently due to initial installation difficulties.

2009, Long Island Sound 138 kV ac XLPE cable:

- One of three buried cables failed within one year of installation, without signs of external aggression.

Two examples have causes yet to be determined or disclosed.

2010, NorNed 450 kV 580 km HVdc cable:

- This HVdc cable, the longest submarine cable in the world, has had two highly publicized cable failures. The first lasting four months beginning January 2010, and another in April 2011. It is unknown if these failures were due to internal causes, or joint failures.

2010, Moyle Interconnector two Monopolar 250 kV HVdc 55 km submarine cables. The Moyle Interconnector, which went into service in 2001, consists of two separate 250 MW cables running 63 km between converter stations in Northern Ireland and Scotland. Moyle has a total capacity of 500 MW.

The following failures may be attributed to anchors.

- 2010-09 – cable fault on one of two 250 MW cables which reduced the Interconnector's capacity to only 250MW for a period of 69 days. As the construction of the Moyle cables is particularly complex, the repair process required specialist personnel, tools, equipment, materials and methods, along with civil engineering works to produce a controlled environment.

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[188] Manitoba Hydro, "Potential Use of Submarine or Underground Cables for Long Distance Electricity Transmission in Manitoba", 2011

- 2011-6-26 – Pole 1 of the Moyle interconnector came out of service as a result of a fault. Testing has established that the fault is located offshore, approximately 17 km from the Northern Ireland coast in a water depth of 140 m. Work is ongoing to identify and repair this fault.
- 2011-8-24 – a fault was recorded on Pole 2 Moyle electricity interconnector. Testing has shown the fault to be located offshore, approximately 3 km from the Scottish shoreline in a water depth of 20 m.

For calculating failure rates based on the survey results, normally both the internal and external failure rates are added together to provide a total. In the case of MI dc cable in the 220 – 500 kV voltage class, the total failure rate would be 0.0998 failures / 100 km-yr as the internal cable failure rate. The SOBI installed cable length is 3 X 36 km over the circuitous route for a total length of 108 km. For this cable based on industry available data, Nalcor could expect that there will be 5.3 cable failures or one cable failure every ten years, approximately. It should be noted that the statistics and the resulting failure rate may not apply to the Strait of Belle Isle due to its location, pattern of naval traffic, and use of cable protection.

Installation of the planned third cable will alleviate the risk of a prolonged outage as full service can be restored in the time it would take to switch in the spare cable, and to take the faulted or damaged cable out of service. There will be a loss of transfer capability as there is only a 150% continuous overload rating on one pole of the HVdc system. Subsequent to a fault it is imperative that steps be taken to repair the damaged cable. As noted in the report, the following steps are generally taken to repair a cable: [189]

- *"Fault Finding*
- *Securing of repair vessel contract*
- *Planning of repair operation*
- *Mobilization of repair vessel and equipment*
- *De-burial of the faulty cable portion*
- *Loading of spare cable and jointing kit*
- *Jointer crew embarks*
- *Repair effected and protection re-established."*

Repair times may be long (many months) as conditions in the Strait of Belle Isle and the availability of repair vessels, and equipment may hamper repair efforts.

8.4.2 Third Party Damage to Submarine Cables

Table 5.7 in the Cigré TB 398, indicates that the sample size for the failure surveys for MI dc cable was 5239 km of installed cable up to 2005. The failure rate is the same as noted previously. However, it is interesting to note that for external failures the failure rate for anchor damage is 0.02 while for trawling it is 0.03. Unknown failures account for the rest at 0.05 failures per 100 km-yr.

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[189] Exhibit CE-44 Rev.2 (Public), Nalcor, "SOBI Marine Crossing Phase 2 Conceptual Design ", May 2011, pg. 29

A number of cable protection systems are described and recommended for submarine cable systems including trenching, tunneling, jet plow, and rock dumping. For the SOBI marine crossing route, a high percentage of the seafloor on the designated cable route consists of bedrock with minimal overburden[190]. According to the SOBI Marine Crossing Phase 2 Conceptual Design report, rock trenching was eliminated as a means of protecting the cable due to the hardness of the bedrock since the technology does not exist.[191]

Cigré TB 398 recommends that for cases where trenching is not possible, the use of concrete mattresses, rock dumping, or both be considered. The use of HDD is also recommended when in close to shore to protect against wave action, or in the case of Strait of Belle Isle, icebergs. The "Lower Churchill Project Rock Berm Concept Development Study Report", CE-42 Rev. 2 (Public) by Tideway BV studied the use of a rock berm and found that this is feasible and will provide appropriate cable protection along the cable route for depths of 40 m to 110 m.

8.4.3 Life Expectancy of Cable Systems

Cable systems are typically designed and tested on the basis of a 40 year life. Actual longevity can exceed this time if loading is not excessive and regular maintenance programs are followed. There is a growing trend to acknowledge that a 50 year actual life may be more realistic, based on service experience with cables less than 500 kV. Comparing this with an approximate 100 year life for overhead line alternatives leads to the conclusion that an underground or submarine cable system would need to be replaced about once during the life of an equivalent overhead line.

8.5 Risk factors

Possible considerations which may affect the implementation of the project in terms of strategy, time and costs include:

- for the proposed long HDDs it should be considered that a failing in the drilling process is possible and would likely require a new attempt with the abandonment of the failed drill. One spare HDD could be provided per each landing, but at a significant cost.
- the schedule and cost estimate for the marine operation are dependent on the weather and downtime which may occur during operational activities.
- the reaction of fishers to the installation, i.e. whether they look at this infrastructure positively or not may be an important issue. The installation and presence of the rock berms could have an impact on the fishers. In addition, claims by fishers for losses could become an issue.
- slippage in the procurement efforts with respect to manufacturing space for cable, or the scheduling of vessels for cable laying or rock placement.

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[190] Overburden is the material that lies above an area of economic or scientific interest; most commonly the rock, soil, and ecosystem that lies above a coal seam or ore body.
[191] Exhibit CE-44 Rev.2 (Public),Nalcor, "SOBI Marine Crossing Phase 2 Conceptual Design", May 2011, pg. 24

8.6 Cost Analysis

Costs for the marine crossing cable system have been estimated by CESI for comparison purposes to Nalcor's estimate. Factors include cable manufacturing, installation, and cable protection. Costs not factored are related to aspects which require a detailed understanding of the territory such as the submarine surveys, the seabed preparation, and effect of adverse climatic conditions during cable laying/installation, maintenance and repair. The implementation plan does not consider other possible contingencies, such as HDD, which may be critical in the schedule and plan of work.

MHI has reviewed the total base cost estimate for the SOBI marine crossing at DG2 and finds it within the range of an AACE Class 4 cost estimate.

8.7 Conclusions and Key Findings

The SOBI marine crossing is a critical component of the Labrador-Island Link HVdc transmission line and will consist of three ±350 kV submarine cables in a 36 km long corridor across the Strait. The cables will have a shore approach with a landing site in the area of L'Anse Amour beach in Forteau Bay on the Labrador side, and in the area of Mistaken Cove on the Newfoundland side.

The conductor has been specified as a ±350 kV single core aluminium or copper cable with mass impregnated (MI) paper insulation with ratings that match the HVdc converter station capabilities. Final cable size selection will be based on a detailed engineering analysis performed by the supplier.

The SOBI marine crossing is extremely complex and poses numerous challenges for cable installation and protection. MHI generally agrees with Nalcor's selection of the route and protection scheme which includes horizontal directional drilling as a means of shore approach and laying the cable on the seabed with a rock berm.

MHI has found the following key findings from the review of the SOBI marine cable crossing:

- The selection of a ±350 kV mass impregnated cable is an appropriate technology selection for the application of an HVdc marine crossing operating at ±320 kV. Other technologies, such as cables with cross-linked polyethylene insulation, have been type tested for this application at ±320 kV but none have been used at this voltage level on a marine HVdc project in the world to date.
- Nalcor's total base cost estimate for the marine crossing at DG2 was reviewed by CESI, an independent engineering firm experienced in HVdc marine crossings. Nalcor's estimate is within the range of an AACE Class 4 cost estimate.
- The iceberg risks are perceived to be significant; however, the application of horizontal directional drilling for shore landings, years of iceberg observations and research performed by C-CORE (a local consulting firm) on the Grand Banks for the various oil projects, and careful route selection across the Strait of Belle Isle have quantified the risks to be less than one iceberg strike in 1000 years. This risk is further mitigated with rock berms, largely for fishing equipment and anchor protection, and a spare cable with separation distance between them of 50 to 150 metres. The research performed by C-CORE found that the risk of a multiple cable

contact by icebergs was reduced with greater separation of the cables. Additional research, monitoring of iceberg roll rates, and bathymetric surveys of earlier iceberg scours should be done to provide a level of validation to further tune the iceberg strike risk model.

- Application of a spare cable with as much separation as practical is a prudent design feature of the Strait of Belle Isle marine crossing considering the potential difficulties of bringing in repair equipment at certain times of the year.