Project Report

January 26, 2013

Emera Newfoundland and Labrador
Maritime Link Project

Engineering Review of the Project

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APPROVALS

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Executive Summary

NSP Maritime Link Inc. (NSPML) is proposing to design, develop and operate the *Maritime Link Transmission Project* between the Island of Newfoundland and Cape Breton, Nova Scotia.

The Lower Churchill Hydroelectric Generation Project will significantly contribute to the increasing production of renewable energy in the province of Newfoundland and Labrador, to the point where surplus energy will be available after meeting current and foreseeable energy requirements. This surplus energy will be available for export through the *Maritime Link* to the existing power grid in Cape Breton, Nova Scotia.

The *Maritime Link* is planned as a new 500 MW, +/-200 kV High Voltage Direct Current (HVdc) transmission system that includes the following elements and associated infrastructure:

- Overhead HVdc transmission lines on the Island of Newfoundland and on Cape Breton in Nova Scotia, and an overhead ac transmission line on the Island of Newfoundland.
- Subsea HVdc cables across the Cabot Strait between Newfoundland and Cape Breton.
- Transition compounds in Newfoundland and Cape Breton near the shore landing locations of the subsea cables, for converting overhead transmission conductors to underground transmission cables and for connecting the underground transmission cables to the subsea cables.
- Two ac/dc converter stations in Newfoundland and Cape Breton.
- AC switchyard facilities in Newfoundland to interconnect the ac/dc converter station and the new and existing overland ac transmission lines, and ac switchyard facilities in Cape Breton to interconnect the ac/dc converter station.
- Shore grounding facilities in Newfoundland and Cape Breton and associated grounding lines.
- Other potential infrastructure, as required.

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The Project has the benefits of leveraging new renewable energy, reducing the need for non-renewable energy projects (and associated potential environmental effects of those projects) in Nova Scotia while providing capacity for more renewable energy to be delivered to the Atlantic region.

Conceptual and functional design for all facilities required to implement the Maritime Link Project have been completed by the end of November of 2012, and market solicitations are in progress to secure firm pricing for two key components of the project: the ac/dc converters in Newfoundland and Cape Breton, and the subsea cable from Newfoundland to Cape Breton. Design development for the terrestrial components, excluding the ac/dc converters, has been advanced to the point that material take-offs have been prepared for all major equipment required for implementation, land requirements have been identified for all facilities, and budget pricing has been obtained from the marketplace for the major equipment and for construction services from contractors.

The Maritime Link Project is technically feasible. All components of the Maritime Link project are comprised of proven technologies, and applications of these technologies have been proven on other projects at similar voltages and power levels.

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1. Introduction

The *Maritime Link* is planned as a new 500 MW, +/-200 kV high voltage transmission system that includes the following elements and associated infrastructure:

- Overhead HVdc transmission lines on the island of Newfoundland and on Cape Breton in Nova Scotia, and an overhead ac transmission line on the island of Newfoundland.
- Subsea HVdc cables across the Cabot Strait between Newfoundland and Cape Breton.
- Transition compounds in Newfoundland and Cape Breton near the shore landing locations of the subsea cables, for converting overhead transmission conductors to underground transmission cables and for connecting the underground transmission cables to the subsea cables.
- Two ac/dc converter stations in Newfoundland and Cape Breton.
- ac switchyard facilities in Newfoundland to interconnect the ac/dc converter station and the new overland ac transmission line, and ac switchyard facilities in Cape Breton to interconnect the ac/dc converter station.
- Shore grounding facilities in Newfoundland and Cape Breton and associated grounding lines.
- Other potential infrastructure, as required.

Hatch was retained by NSP Maritime Link Inc (NSPML) to undertake conceptual design studies and functional design development for the terrestrial components of the Maritime Link Project, based on preliminary system planning studies and conceptual design decisions completed by NSPML in consultation with Newfoundland and Labrador Hydro and Nova Scotia Power Inc. This report summarizes the design development undertaken by Hatch, starting from these conceptual design decisions.

Section 2 of this report includes a description of the project, including documentation of studies and conceptual design decisions undertaken by NSPML prior to the engagement of Hatch. Section 3 includes documentation of routing and siting investigations completed during the engagement of Hatch on the project, which have been undertaken cooperatively by NSPML and Hatch. Section 4 provides additional details of the design development undertaken by Hatch, including design criteria, design configurations, facility drawings and equipment requirements. Section 5 contains a description of how the Maritime Link system will be operated by NSPML.

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2. Project Overview

2.1 Purpose of Project

The primary purpose of the Maritime Link Project is to provide a transmission path for delivery of 500 MW of power from the Island of Newfoundland to Cape Breton Island in Nova Scotia. Half of this power delivery, 250 MW, must be continuously available or "firm." As such, the transmission path must be highly reliable to permit virtually uninterrupted power delivery throughout its 50 year service life.

The capacity of the Muskrat Falls Generating Station will be 824 MW. Nalcor requires a portion of this supply for Newfoundland domestic needs, but up to 500 MW will be available for export to Nova Scotia. Of this amount, Nova Scotia will receive a contract delivery of 170 MW, plus a supplemental block of energy that NSPML will receive during the first five years of Maritime Link operation, which will allow NS Power to retire coal-fired generators in Nova Scotia. The balance of the 500 MW export will be available for sale to NS Power by Nalcor, or it could pass through Nova Scotia to buyers in New Brunswick, Prince Edward Island or New England.

The main purpose of the Maritime Link Project is to deliver power from Newfoundland and Labrador to Nova Scotia, and this will be its usual mode of operation. However, in special and unusual circumstances, critical capacity shortfalls may occur on the Island of Newfoundland, and the Maritime Link Project will provide a path for power to flow in the opposite direction, from Nova Scotia to Newfoundland and Labrador. The design of the facility must accommodate this mode of operation as well.

2.2 System Alternatives Considered and Selected Project Configuration

Early system development investigations were undertaken by Nalcor Energy as part of the planning for the Lower Churchill project development, and Emera Inc has become progressively engaged in these development studies as the design concepts for the interconnection between the Island of Newfoundland and the Canadian Maritimes have crystallized. The following sections document investigations undertaken by Nalcor Energy and Emera Inc. (and its subsidiary companies) prior to the commencement of preliminary design development by Hatch.

Before beginning detailed project design, project planners from Nalcor and Emera/NSMPL made various decisions about the project's conceptual design, its transmission routes, and the location of key facilities. Sections 2.2.1 through 2.2.12 explain the reasons behind these choices. As such, the completed system design decisions documented in these sections were the starting point for the Hatch services, and constituted the framework for the design development undertaken by Hatch.

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2.2.1 *Physical Configuration*

There are three options for the physical configuration of transmission lines: overhead, underground and submarine (subsea). The decision between these options turns on routing considerations, electrical design considerations and cost considerations. For any transmission line path that offers route options including overhead, underground and submarine, overhead transmission is the lowest cost solution, by a multiple typically exceed 2 to 1, meaning that route planners will often accept a considerable increase in route length to avoid areas requiring underground or submarine construction (e.g., urban areas or large water crossings). This is principally due to the high cost of manufacturing the specialized high-voltage cables used for underground and subsea applications, which is greater than the total cost of materials and installation for an overhead transmission line of the same voltage level and comparable power transmission capacity. In addition, installation costs for underground and subsea cables are a factor, as underground cables require costly excavation and burial/protection, and subsea cables require deployment of expensive ocean-going cable-laying ships and specialized methods of laying and protecting the cables on the sea bed. Underground or subsea transmission options are normally considered only when terrain conditions along the desired transmission path make overhead transmission impracticable.

For the crossing of the Cabot Strait, overhead transmission is clearly impractical and subsea cable construction is the only option. For the terrestrial sections of the transmission path, overhead and underground transmission are options, and a comparison of these options has been prepared, as summarized in Table 2-1 below.

Table 2-1: Comparison of Overhead and Underground Transmission Options

Alternative Means	Technical Feasibility	Economic Comparison	Selected Means
Overhead	Considered feasible.	Least cost option.	Selected means
Buried	Considered feasible although the geology of the terrain in NL is technically challenging.	Considered prohibitively expensive	

NSPML proposes to develop the Maritime Link Project using overhead transmission, except for the ocean crossing from Newfoundland to Cape Breton. Other short sections of the transmission line may be built underground, if physical constraints prevent construction of overhead facilities.

2.2.2 *Alternating Current Transmission vs. Direct Current Transmission*

The decision between Alternating Current (ac) transmission and Direct Current (dc) transmission turns on electrical design and cost considerations. Alternating Current

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transmission is the dominant form of transmission used around the world, including the provinces of Nova Scotia and Newfoundland and Labrador, because of a variety of advantages in the area of planning flexibility, interconnectivity and operational flexibility. Transmission voltage levels can be readily and inexpensively transformed to levels appropriate to a particular transmission application, and it is comparatively straightforward to make future connections to an ac transmission circuit along the line route through construction of switching and transformer stations.

AC transmission is also the least-cost transmission option for most power transmission applications involving small to intermediate power transmission over short distances, because of the high cost of converting ac power to dc power (and vice versa). Since all major transmission projects involve connections between existing ac transmission systems at each end of the transmission line, a decision to implement dc transmission requires conversion of the ac transmission voltage to dc transmission voltage, and the ac/dc converters required to complete this conversion are complex and expensive facilities. Depending on voltages and power levels, the cost of these ac/dc converters can be $100M or more at each end of the transmission circuit. Once the ac voltage has been converted to dc voltage, the cost of the dc power transmission circuits is lower per unit length than ac power transmission circuits of comparable power transmission capacity, and the power losses on dc transmission circuits will be lower than the power losses on the corresponding ac transmission circuits. However, these cost savings must accrue over a significant transmission route length in order to offset the high cost of conversion facilities at each end. At power transmission levels of 1000 MW or more, and for power transmission distances greater than 500 km over land, the economics of dc transmission can be attractive compared to ac transmission.

However, notwithstanding these economic considerations for land-based transmission applications, ac transmission is not technically feasible for long and continuous lengths of power transmission routed through underground or submarine cables, because of electrical design constraints. Electrical cables are inherently capacitive in nature, due to the close proximity of the electrical conductors and their associated return paths (through grounded cable sheaths and the earth itself). Because of this electrical property of electrical cables, and the interaction between ac voltage and the cable capacitance, part of the current delivered into an ac cable will be used to supply (or “charge”) the cable capacitance. As the length of the cables increases, the percentage of cable current devoted to charging the cable capacitance will increase to the point that no real power can be delivered through the cable.

A commonly used rule of thumb is that ac transmission is only technically feasible up to a total continuous length of 50 km of underground or submarine cable. With specially designed low-capacitance cables and aggressive reactive compensation techniques, this limit can be expanded somewhat, but with diminishing returns. Some of the longest ac transmission projects in the world include the 104 km UK-Isle of Man subsea cable at 90 kV and 60 MW, the 87 km Victoria Desalination underground cable at 220 kV and 145 MW, and the planned 162 km Norway - Martin Linge subsea cable at 145 kV and 55 MW. Since the shortest ocean crossing from Newfoundland to Nova Scotia is wider than the longest AC underground or

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submarine cable built to date, and the 500 MW power requirement exceeds the power transmission capacity of any of these projects by a wide margin, it is clear that the transmission requirements of the Maritime Link Project cannot be practically achieved using ac transmission. On that basis, dc transmission is the only feasible solution for this ocean crossing. A summary of the comparison is provided in Table 2-2 below.

The Maritime Link Project is therefore conceived as a dc transmission connection between the existing power systems in Newfoundland and Nova Scotia, which are today exclusively ac transmission systems. Implementation of this project requires conversion of ac power to dc power at each end of the dc transmission connection, to facilitate interconnection of the new transmission link into the host power systems in Newfoundland and Nova Scotia. However, the high cost of the ac/dc converters does not factor into the decision between ac and dc transmission across the Cabot Strait. The requirement for ac/dc conversion is necessitated by the requirement for HVdc transmission across the Cabot Strait. With this requirement firmly established, the decision between ac and dc transmission over the land-based sections of the transmission route will be driven by economic and operational considerations. This evaluation is presented in Section 2.2.6 below.

Table 2-2: Comparison of AC and DC Transmission

Alternative Means	Technical Feasibility	Economic Comparison	Selected Means
HVac	Considered infeasible for the subsea crossing of the Cabot Strait due to cable capacitance resulting in degradation of power transmission capability. Feasible for the land-based sections of the transmission route.	Economics not considered for subsea section of the line, due to technical infeasibility. For land-based sections of the line, cost of ac transmission will exceed cost of dc transmission, due to need for third conductor in ac option.	
HVdc	Considered the only feasible option for the subsea crossing of the Cabot Strait. For land-based line sections, HVdc is technically feasible.	For land-based sections of the line, cost of ac transmission will exceed cost of dc transmission, due to need for third conductor in ac option.	Selected means for subsea section of line route.

2.2.3 AC/DC Conversion Technology

DC transmission projects must interconnect with ac transmission systems at each end of the dc transmission link, and the dc transmission voltage must be converted to ac transmission voltage at each terminal to facilitate these interconnections. At the sending end of the transmission link, the ac voltage must be transformed to an appropriate voltage level, and then the ac waveform must be rectified and smoothed to produce a steady fixed dc voltage. At the receiving end of the

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transmission link, the fixed dc voltage must be inverted into alternating plus and minus voltages at the target system frequency, filtered to produce a clean sinusoidal waveform, and then transformed to a voltage level equivalent to the ac system that is being interconnected. The sending-end transformation-rectification-smoothing process and the receiving-end inversion-filtering-transformation process are carried out by a class of electrical facilities known as ac/dc converters.

There are two ac/dc conversion technologies available in the marketplace at the present time: Line Commutated (Current Source) Conversion technology, known as LCC technology, and Voltage Source (Self Commutated) Conversion technology, known as VSC technology. LCC technology has dominated the ac/dc conversion market for most of the last 40 years until the invention of Voltage Source Converters in the 1990s, and VSC technology has made steady inroads in new applications since that time. The difference between the two technologies lies in the high-voltage solid-state devices that form the heart of the rectification and inversion process. LCC systems use high-voltage thyristors for this purpose, whereas VSC systems use Insulated Gate Bipolar Transistors (IGBT).

Implementation of ac/dc conversion using IGBT results in a cost saving compared to ac/dc conversion using thyristors, so VSC technology offers lower initial costs compared to LCC technology. VSC technology also offers operational advantages over LCC technology in applications involving weak ac transmission systems at either the sending or receiving end of the dc link, particularly systems with low fault current and systems with weak reactive power support. Reactive power support is traditionally provided by strong generation sources connected to the ac system close to the point of interconnection, and is important in an LCC installation to maintain the stable ac system voltages required by LCC technology.

Furthermore, VSC technology is a good fit for applications with highly capacitive dc transmission circuits, particularly underground and submarine cable systems. For these reasons, Voltage Source Converters using IGBT are gradually taking over the lower end of the dc transmission market, and these converters are gaining market penetration at progressively higher dc system voltages and power transmission requirements. At the present time, all HVdc projects around the world, either planned or under construction, which contemplate a power transfer level less than 700 MW (at least 8 projects), are being developed using VSC technology. Most of the publicly announced projects up to 1000 MW are also planned as VSC installations.

The operational advantages of VSC technology are particularly relevant for the Maritime Link Project. With a weak ac transmission system at the Newfoundland sending end, and relatively weak reactive power support at both ends of the dc transmission link (particularly with planned reduction of coal-fired generation in Cape Breton), implementation of LCC technology would present significant challenges for this project, whereas VSC technology is particularly suited for such applications. System studies by NALCOR and Emera, supported by ac/dc converter vendors, have indicated that additional dynamic reactive power support, in the form of synchronous condensers, would be required in Newfoundland and the Cape Breton area if the Maritime Link Project were implemented with LCC technology.

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A comparison of LCC and VSC technology for application on the Maritime Link Project is provided in Table 2-3 below. Based on this analysis, NSPML has chosen to proceed with VSC technology for the Maritime Link Project.

Table 2-3: Comparison of LCC and VSC Technologies

Alternative Means	Technical Feasibility	Economic Comparison	Selected Means
Line Commutated Conversion (LCC) Technology	Considered feasible	Higher cost option, considering conversion cost, ac system upgrade costs, dc transmission costs	
Voltage Source Conversion (VSC) Technology	Considered feasible	Least cost option, considering conversion cost, ac system upgrade costs, dc transmission costs	Selected.

2.2.4 *Selection of Underground/Submarine Cable Technology*

Regarding the submarine cable system, two technologies have dominated the market for HVdc submarine cable applications in recent years. For high-voltage and high power transmission applications, Mass Impregnated Paper insulated cables have dominated the market for many years, but extruded plastic insulation technologies have traditionally offered cost advantages and have made steady inroads at progressively higher voltage levels and power transfer capabilities. To date, the highest power and voltage level for an HVdc extruded plastic insulated submarine cable was the Eirgrid East-West Interconnector between Ireland and Wales, commissioned in 2012 as a 500 MW and +/- 200 kV cable link, Numerous HVdc projects are currently in development that will push application of plastic insulated HVdc cables to much higher power and voltage levels.

Mass Impregnated (MI) Paper insulated cables utilize oil-impregnated paper tapes wrapped around the central core conductor, and these cables have a proven track record of successful project implementation at voltage and power levels higher than the Maritime Link Project. Extruded plastic insulated cables are manufactured with a polymeric plastic insulation (typically cross-linked polyethylene or XLPE for short) extruded over a central core conductor, and these cables have traditionally been applied in conjunction with IGBT-based (VSC) converters to achieve the lowest total cost of conversion and cable transmission. As such, the voltage and power levels for extruded plastic cable installations have grown in lockstep with the expanding applications of VSC technology.

A decision has not as yet been made as to the type of cable technology to be utilized on the Cabot Strait crossing. Both MI cables and XLPE cables have been deemed viable for application on the Maritime Link Project, since XLPE cables have been successfully commissioned at voltage and power ratings equal to those considered for the Maritime Link Project and MI cables have a long project history at higher voltage and power ratings than the

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Maritime Link Project. The decision between cable technologies will be made at the conclusion of the cable solicitation process, and is expected to be a trade-off between the traditionally lower costs of XLPE cables and the longer operating history of MI cables.

NSPML has called for proposals to design, supply and install the subsea cable system, and proponents have the option to supply either MI or XLPE insulated cables. Proponents for the cable supply contract are required to offer documentary evidence of the technical viability and successful project history of the cable technology that is being offered, and the long-term viability of the proposed cable technologies will be an important part of the tender evaluation process. Pending a final decision on the cable technology to be used, project cost estimates are based on a conservative assumption that MI cables will be used for the project.

2.2.5 Interconnection Locations

Important decisions must be made regarding the locations for interconnection of the new transmission link into the existing ac transmission grids in Newfoundland and Nova Scotia, and the locations where the ac transmission will be converted to dc transmission. Interconnection locations have been chosen on the basis of the strength of the existing transmission system to accommodate the delivery of 500 MW of power.

In Newfoundland, Bottom Brook substation and Bay D'Espoir generating station were examined as optional locations for the ac interconnection. Bay D'Espoir was eliminated because the longer length of subsea cable to Nova Scotia made this a high-cost project element with high execution risks. Bottom Brook was chosen because it was electrically strong enough to deliver 500 MW into the dc transmission link, and because it is geographically proximate to the landfall location of the shortest crossing of the Cabot Strait. To ensure reliability of supply, the ac connections to Bottom Brook Substation will need to be strengthened, and these requirements are described in Section 2.2.12 below.

In Nova Scotia, the 345-kV Woodbine Substation is suitable for receipt of the 500 MW delivery, as this substation is today a major hub for power generation in Cape Breton and delivery of this generation to load centers throughout Nova Scotia. The station must be expanded to accommodate the interconnection of the ac/dc converters, and to provide increased capacity to transfer power from the 345-kV system to the 230-kV system of NS Power. Section 2.2.12 discusses these network modifications.

2.2.6 AC/DC Converter Locations

With the terminal locations for the Maritime Link Project chosen to be Bottom Brook Substation in Newfoundland and Woodbine Substation in Cape Breton, the primary transmission path for the project consists of a route from Bottom Brook Substation to the Newfoundland sea shore, the ocean crossing from the Newfoundland sea shore to the Cape Breton sea shore, and a route from the Cape Breton sea shore to Woodbine Substation. While the cable crossing from Newfoundland to Nova Scotia must be built as a dc transmission link, as discussed earlier, the overland sections in Newfoundland and Nova Scotia could be built as either ac or dc transmission, with the ac/dc conversion facilities

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constructed at any point between Bottom Brook and the Newfoundland sea shore and at any point between the Nova Scotia sea shore and Woodbine. However, as shown in Table 2-2 above, dc transmission offers significantly lower costs per unit length than ac transmission of similar capacity and exhibits lower electrical losses, so the least-cost option is to build dc transmission throughout the overland route sections and to install the ac/dc converters at Bottom Brook and Woodbine Substations. This economic advantage is further supported by operational considerations, including a preference for readily accessible sites in populated areas for maintenance reasons, and a preference for sites that are outside the influence of coastal saltspray.

NSPML has decided to build the ac/dc converter stations immediately adjacent to the Bottom Brook and Woodbine substations.

2.2.7 System Voltage Level

For the required 500 MW power transfer level, project planners considered HVdc voltage levels of +/- 200 kV and +/- 250 kV. Higher voltage levels permit transmission of greater amounts of power over the transmission link, at higher efficiency (i.e., lower electrical losses), but this added capacity is realized at a higher initial construction cost. Another important consideration is the decision to proceed with VSC technology for ac/dc conversion, which has a limited history of applications at higher transmission voltages. In a similar vein, the submarine cable system may be built with either MI or XLPE insulation, but the XLPE insulation system also has limited applications at higher transmission voltages. The system voltage is selected to balance these competing considerations

The system will have two separate poles, consisting of a positive and negative pole that together deliver 500 MW. Each pole can operate independently, delivering 250 MW using a common neutral return path.

- For the **+/-** 200 kV system, the current flow in each pole will be 1250 A during maximum power delivery.
- For the **+/-** 250 kV system, the current flow in each pole will be 1000 A during maximum power delivery.

The overhead line portion of the project can be readily designed to accommodate either of these voltage levels, and presents no constraint on the voltage selection decision, For the subsea cables, the 200-kV voltage level is readily achievable using either of the two cable technologies that are commonly used for HVdc transmission, whereas the 250-kV voltage level has not yet been fully proven for the XLPE insulation system. Thus the +/- 200 kV system voltage offers the benefit of keeping all options open for the subsea cable technology, and ensuring that technological risks are well managed for either cable option.

The VSC converters are another component in the Maritime Link project where the power levels and corresponding voltages and currents approach the limits of proven technology.

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The highest voltage levels for any VSC system commissioned to date are +/- 200-kV bipoles for the TransBay Cable in the USA and the “EirGrid” East-West Interconnector between Ireland and Wales, and a 350-kV monopole for the Caprivi Link between Zambia and Namibia. While there are a significant number of projects planned for commissioning in the period 2013 to 2015, that will push the threshold for VSC technology to higher voltage levels, +/- 200 kV is currently the threshold for successfully commissioned and operational bipolar VSC projects.

The other important decision factor is the current level delivered by the ac/dc converters. The 1250 Ampere current level for the +/- 200 kV voltage option and the 1000 Ampere current level for the +/- 250 kV voltage option straddle the threshold of recent VSC project implementations. The TransBay (USA) ac/dc converters operate at a 1000 Ampere level and the East-West (Ireland-Wales) converters operate at a 1250 Ampere level, and virtually all previous VSC projects operate at current levels less than 1000 Amperes. A significant number of VSC projects are planned or under construction, which will raise the threshold to 1300 Amperes and higher, including the Borwin Alpha, Borwin2, Dolwin1 and Dolwin2 Projects in Germany, all due to be commissioned between 2012 and 2013.

Based on studies undertaken by NSPML, in consultation with NLH and NSPI, a decision has been taken to implement the Maritime Link Project at the +/- 200-kV operating voltage.

2.2.8 Neutral Return Path

Bipolar and dual-monopolar dc transmission systems require a solid and reliable return path between the converter stations in addition to the pole conductors, because any unbalance between the power sent on the positive and negative poles will return through the return path. During bipolar operation, unbalance currents between the poles (approximately 12.5 Amperes or 1% of full load current) will flow through the return path. During bipolar operation, full load current of 1250 Amperes may flow through the return path. Because the Maritime Link Project requires 250 MW of “firm” transmission capacity, it must maintain at least 250 MW of power in the event of planned or unplanned outages on either the positive or negative pole. In the event of such an interruption, the return path will be a primary path for the reduced power transmission. Very low resistance must be achieved in the return path to ensure stable and reliable performance of the ac/dc converters.

There are two principal means of providing a return path rated for full system current: metallic return and earth return. These options are presented graphically in Figures 2-1 and 2-2 below. Metallic return requires installation of a fully rated metallic conductor from end to end along the transmission path, whereas ground return requires establishment of a low resistance connection to earth that will permit the return current to flow in a virtually infinite number of paths through the earth from the receiving end to the sending end of the HVdc link.

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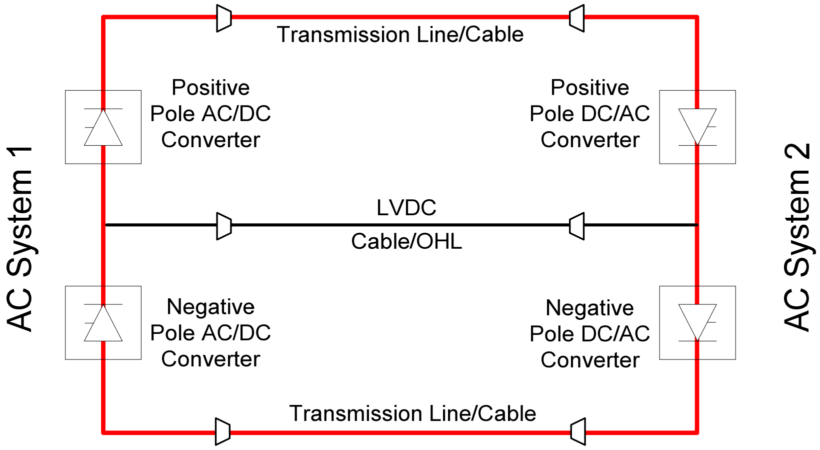

Figure 2-1 Metallic Return

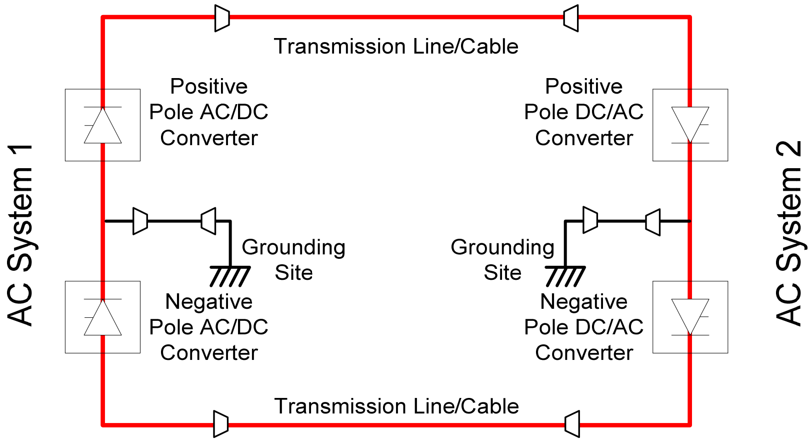

Figure 2-2 Earth Return

Metallic return requires significantly larger capital costs than earth return, due to the requirement for a third conductor along the transmission path, including the subsea section. Metallic return also leads to significantly higher operating losses than earth return, because the total resistance of the return path will be a fraction of an ohm in the case of earth return and several tens of ohms in the case of metallic return. HVdc projects requiring fully rated monopolar operation are consistently built with an earth return rather than metallic return, except in circumstances where earth return is not practical due to environmental considerations or proximity of metallic infrastructure within the zone of influence of the grounding site.

Typically, the only disadvantages of using earth return in HVdc systems are the technical challenges of achieving sufficiently low earth resistance in some earth conditions, and in situations where low earth resistance is achievable, the impacts of dc stray currents. The grounding sites are designed and located to mitigate any possible impacts.

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Based on preliminary analysis, no major issues are foreseen in achieving an effective earth return path for the Maritime Link Project. Since technically feasible options exist for earth return, and the impacts of dc stray currents can be effectively mitigated, NSPML has decided to implement the Maritime Link Project using an earth return path.

The effectiveness of earth as a return path is dependent on achievement of a very low resistance connection to ground. This is achieved through construction of a grounding site, and there are two main types of grounding sites used for HVdc transmission projects: grounding sites in contact with earth, and grounding sites in contact with sea water. Grounding sites in contact with sea water can be further subdivided into three types: sites developed in the sea; sites developed in a man-made shore-line pond or natural lagoon; and sites developed at a beach in well casings immersed in saturated soil at a distance inland from the shoreline.

The geology of Newfoundland and the northern part of Nova Scotia is such that a grounding site in contact with earth is not considered a viable option. With high electrical resistivity and low thermal conductivity, it would be difficult if not impossible to achieve a low resistance ground connection and effective heat dissipation at the grounding site, and the risk of thermal runaway conditions is unacceptable.

A sea grounding site is not considered desirable due to construction challenges in the marine environment, possible impacts of construction and grounding site operation on the marine environment, and accessibility issues for maintenance of the facilities. A beach grounding site is not considered desirable, due to design and performance issues arising from the prevalence of rock formations at beach locations in the area, and the lack of substantial soil overburden above these rock formations.

Shore grounding sites, on the other hand, offer the advantages of low electrical resistance to remote earth due to the conductivity of sea-water, and ease of access for future maintenance.

Therefore a shore grounding site, isolated from the sea by a permeable breakwater, is the preferred option for the Maritime Link HVdc scheme. The proposed converter sites for the Maritime Link Project are located within 50 km of the ocean at each end of the transmission link, and will be connected to the grounding sites by dedicated grounding lines.

As a rule, the grounding sites will carry very little current, based on normal unbalance between the positive and negative poles. Only a sustained outage of a pole conductor will require sustained use of the earth return path. As rare as these event may be, the grounding sites must be designed to carry full rated system current for an extended time without incident.

2.2.9 Location of Shoreline Grounding Sites

Site selection for shoreline grounding sites is driven by shoreline bathymetry, proximity to infrastructure and population centers, oceanographic considerations, distance from the converter station, constructability requirements, and environmental and land acquisition and access

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requirements. The prospective grounding sites must be suitable to achieve very low ground resistance and low impact on surrounding infrastructure and the environment. The near-shore bathymetry and sea-bed geology of the sites must be suitable for construction of a breakwater to enclose a shoreline pond with adequate depth at the toe of the breakwater in the pond for submerged grounding elements under all tidal conditions, and the wave activity in the area must be conducive to long-term stability of the breakwater. The sites must be available for fee-simple acquisition, and the sites must be accessible by road for future maintenance activity. Existing metallic infrastructure in the vicinity of the sites must be well documented and well understood, and it is preferable that the grounding site shall be located several kilometers away from any existing linear metallic infrastructure (i.e., metallic infrastructure with conductive connection to other remote metallic infrastructure).

Candidate sites were selected based on a high level review along the shorelines within a radius of 50 km from the converter stations. Preliminary locations for the grounding sites were selected based on criteria that included proximity to the converter station, proximity to existing transmission and/or road rights of way, extent of natural shore protection, and proximity to buried metallic infrastructure. Sites considered in Newfoundland included locations near Shallow Cove, St. George’s, Port Harmon and Indian Head. Sites considered in Cape Breton included locations near Alder Point, Sydney Harbor, Gabarus Bay, Donkin, St. Andrew’s Channel, Mira Bay, Big Lorraine, Little Lorraine and East Bay.

Field reconnaissance and technical analysis was undertaken to validate the selection criteria and develop a short-list of credible sites. Concurrently, local knowledge was obtained through research and stakeholder consultation on key environmental and socio-economic criteria such as land availability, land protection, Mi’kmaq interests, commercial fishery interests, and potential for interaction with species of conservation interest.

Based on all of these factors, the following sites were determined to be feasible:

Newfoundland	**Cape Breton**
St. George’s	NW Arm Sydney Harbour
Port Harmon entrance to channel	Gabarus Bay
St. George’s River estuary	Mira Bay
Indian Head	Big Lorraine
	Little Lorraine

Comparisons were undertaken on the four feasible sites in Newfoundland, and the five feasible sites in Cape Breton, based on technical, land tenure, access, constructability, maintainability and cost considerations. The results of these evaluations are summarized in Tables 2-4 and 2-5 below.

The analysis to date supports a preference for the St. George’s site in Newfoundland, followed by Indian Head as a second choice. Similarly in Cape Breton, the Big Lorraine and Little Lorraine sites were evaluated as the first and second choice.

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Table 2-4: Summary of Assessment of Alternative Grounding Sites – Island of Newfoundland

Alternative Means	Technical Feasibility	Economic Comparison	Selected Means
St. George's	Considered feasible.	Among least cost options.	Selected alternative
Port Harmon entrance to channel	Considered feasible although design of breakwater expected to be challenging due to wave action.	Protection against the prevailing wind and wave direction would result in a robust and costly breakwater.	
St. George's River estuary	Considered technically feasible although channel between estuary and St. George's Bay creates a challenge for effective mitigation of salmon migration.	Among least cost options.	
Indian Head	Considered feasible, but challenging for breakwater development due to shear sea bed slope near shore line, for arranging required area for the pond, and for access.	Higher cost option.	Second choice

Table 2-5 Summary of Assessment of Alternative Grounding Sites – Cape Breton

Alternative Means	Technical Feasibility	Economic Comparison	Selected Means
NW Arm Sydney Harbour	Considered feasible, but challenges due to nearby infrastructure.	Highest cost option, due to expense of mitigation of impacts on surrounding infrastructure.	
Gabarus Bay	Considered feasible.	Among lower cost options	
Mira Bay	Considered feasible.	Among lower cost options	
Big Lorraine	Considered feasible	Among least cost options	Selected alternative
Little Lorraine	Considered feasible	Among least cost options	Second choice

2.2.10 Cable Routing and Locations of Subsea Cable Landing Sites

The principal driver for the selection of the cable route and the shore landing sites for the subsea cables is the minimization of the route length of the subsea cables, because of the very high installed cost of these cables per unit length. Other factors that have been considered include the coastal topography at the landing sites, the near-shore geology, and the impact of the landing sites on the submarine cable route and the overland transmission routes.

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On the Newfoundland side of the Cabot Strait, sites near the Southwestern tip of Newfoundland are clearly preferred, as this area offers the shortest possible cable route to Cape Breton. In Cape Breton, landing sites on the Cape Breton Highlands peninsula were considered, in the Wreck Cove area, but these options were quickly discarded due to the added cost and implementation challenges for the overhead HVDC construction in this area. After ruling out the Highlands area, only sites in the North Shore areas to the east and west of Sydney Harbor were considered.

Based on this preliminary definition of prospective cable landing areas, a preliminary cable route was selected for study, and extensive bathymetric surveys were undertaken of the sea bottom between these prospective landing areas. The survey helped in identification of corridors suitable for installation of the subsea cables, and in refining the selection of the cable landing sites.

In Newfoundland, planners focused on the area near the Southwestern tip of the island, and identified a site near Cape Ray, based on nearshore geological conditions, stakeholder/environmental constraints, and ease of site access.

Within the North shore areas considered in Cape Breton, two alternative sites were evaluated, at Lingan and at Point Aconi. Point Aconi was chosen as the preferred site, based on a lower submarine cable route length, coupled with more suitable coastal topography and nearshore geology. Table 2-6 summarizes the results of the comparison.

Table 2-6: Comparison of Alternative Cable Landing Sites in Cape Breton

Alternative Means	Technical Feasibility	Economic Comparison	Selected Means
Point Aconi Generating Station	Considered feasible.	Least cost option for subsea cable, higher cost for overland transmission.	Selected means
Lingan	Considered feasible, but presents risks due to coastal topography, nearshore geology, and stability of the seafloor.	Higher cost option for subsea cable, due to longer cable route and existence of numerous crossings of existing communication cables. Lower cost for overland transmission, due to greater route length from Point Aconi to Woodbine	

2.2.11 Method for Onshore/Nearshore Cable Installation

The installation methods for the subsea cables are an important factor in the reliability of the cable system, because the cables are exposed to damage from a variety of causes. In deep waters (at least 15 meters), the risks can be adequately addressed by a combination of cable spacing on the ocean floor, hydro-jet installation techniques to plow the cables into the sea floor, and stone berms or concrete mattresses for cable protection over ocean-bottom rock

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outcroppings. However, in the nearshore approaches to the cable landings, the number and severity of the risk factors increases, creating increased risks of damage to one or both pole cables.

In shallow waters, the cables are exposed to potential damage from a variety of sources including seafaring vessels and anchors, pack ice scouring, and commercial fishing operations. The traditional method of securing protection against these external influences is to bury the cable at sufficient depth below the ocean floor to avoid or minimize the risk. This is achieved by one of three burial techniques: trenching, horizontal directional drilling (HDD) and micro-tunneling. All three of these installation techniques were considered technically feasible by NSPML, although trenching was considered to present additional schedule risks during installation in the event of inclement weather and incremental environmental impact on sensitive coastal habitats, and micro-tunneling was considered to carry additional execution risk.

Table 2-7 below documents the comparison of the three available installation techniques, from a technical, economic and environmental perspective. Horizontal Directional Drilling (HDD) was chosen as the preferred technique, as it avoids the disturbance of sensitive coastal habitats and minimizes project execution risk.

Table 2-7: Comparison of Near-Shore Cable Installation Techniques

Alternative Means	Technical Feasibility	Economic Comparison	Selected Means
Horizontal Directional Drilling (HDD)	Considered feasible.	Higher cost than trenching.	Selected means
Trenching	Considered feasible, although inclement weather poses a risk to activity and schedule.	Least cost option	
Micro-tunnelling	Technical feasible but not selected because of higher execution risk.	Higher cost than trenching.	

2.2.12 *System Reinforcement Requirements*

System studies undertaken by NALCOR and NSPML have demonstrated that the transmission system in the vicinity of Bottom Brook Substation has sufficient strength to supply 500 MW of power to the ac/dc converters, with all Newfoundland transmission facilities in service. However, Bottom Brook Substation is connected to the Newfoundland transmission grid by just two transmission circuits: TL211 from Massey Drive, and TL233 from Buchans. In the event of a contingency loss or maintenance outage to either of these

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230-kV circuits, there would be insufficient transmission capacity to deliver the 500 MW into Bottom Brook needed for the Maritime Link Project. A third 230-kV line into Bottom Brook Substation, independent of the supply path to Massey Drive and Buchans, would provide added security for the 500 MW delivery into the Bottom Brook Substation. Given that the principle source of supply for the 500 MW will be the HVdc supply into Soldier's Pond Substation (St. John's) from the Lower Churchill project, the preferred source for the new transmission connection to Bottom Brook should be along a strong transmission path eastwards connecting Bottom Brook to Soldier's Pond, independent of the supply path from Soldier's Pond to Massey Drive and Buchans. Planning studies have demonstrated that a 230-kV transmission link from Granite Canal to Bottom Brook would ensure reliable delivery of 500 MW of power to Bottom Brook under credible outage conditions on the Newfoundland transmission system.

The Nova Scotia end of the connection requires upgrades to accommodate the 500 MW delivery, including a minimum of 170 MW to be consumed in the province of Nova Scotia, and up to 330 MW to be wheeled through Nova Scotia. To reliably accommodate the delivery of 500 MW, and the prospective wheeling requirements, Woodbine Substation will need a second 345/230-kV transformer, and an extension of the 230-kV bus to facilitate two additional 230-kV transmission lines.

In addition to the Woodbine substation upgrades, NS Power has identified a number of network upgrades that are needed to facilitate the power delivery and wheeling requirements associated with the project. The upgrades include reinforcement and modification of substations and transmission lines in the NS Power network, as summarized below:

- L-6513 Rebuild/Upgrade Line Terminals
- Strait Crossing: Separate L-8004/L-7005
- L-6511/L-6515//L-6552 Upgrades

2.2.13 Routing of Transmission Lines

(a) **Overhead HVDC Transmission Routing**

The +/- 200 kV dc overhead line between Bottom Brook and Cape Ray will be routed almost entirely alongside existing ac transmission facilities south of Bottom Brook, including 138-kV and 69-kV transmission lines owned by Newfoundland & Labrador Hydro. The rights of way for these existing transmission lines will be expanded to accommodate the new HVdc transmission line. The estimated route length of this corridor is 142 km.

The +/- 200 kV dc overhead line between Point Aconi and Woodbine will also be routed almost entirely alongside existing ac transmission lines, in this case a single 230-kV transmission line (designated L7015) owned by Nova Scotia Power Inc. Over most of the route length, the right of way of the existing transmission line will be expanded to accommodate the new HVdc transmission line. Along some selected sections of the line

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route, the existing line L7015 is routed in close proximity to other transmission infrastructure, and the existing transmission circuits through these areas must be reconfigured to provide sufficient space for the new HVdc transmission line. The route length of the HVdc line in Nova Scotia is 46 km, excluding the short underground section stated in the following paragraph.

In the final approach to the Woodbine converter station, the new HVdc transmission line will be required to cross several existing transmission circuits. An aerial crossing of multiple transmission circuits raises an unacceptable reliability risk, and an alternative solution was sought for this crossing. It has been proposed to use underground cables to avoid the aerial crossing for this 1 km length.

(b) Submarine Cable Routing

For the subsea cable, route selection has been guided by four factors:

- The need to minimize the route length and resulting cost.
- The need to avoid major obstructions and jagged rock outcroppings.
- The need to avoid existing subsea infrastructure.
- The need to avoid environmentally sensitive areas.

NSPML acquired detailed imagery of the sea floor, along with soil sampling and sediment collection and analysis. In areas where remotely operated vehicles identified such features as visual depressions of obstructions, additional surveys were carried out. Near the shore. LIDAR surveys were used for shallow water assessment of the seafloor terrain. In addition, studies were completed regarding sea currents, silt migration and ice patterns.

The selected route very nearly follows a straight line between Cape Ray and Point Aconi. The route has been defined as a 2000-meter wide study corridor, to facilitate the Environmental Assessment process and to provide flexibility for NSPML and the cable supplier to adopt a final route and cable spacing strategy that minimizes risk of cable damage, maximizes the reliability of the cable system, avoids sensitive habitats and minimizes interactions with commercially sensitive fisheries. The estimated subsea route length is 170 km.

(c) 230 kV ac Transmission Routing

For the proposed new 230-kV ac transmission line between Granite Canal and Bottom Brook, NSPML considered two: one route leaving Granite Canal and traveling North of Granite Lake, and a second route traveling South of Granite Lake. Both the Northern route and the Southern route were considered technically feasible. Although the Southern route will have a greater footprint overall than the Northern route, the Southern route follows existing rights of way to a greater extent than the Northern route, and will cause less disturbance and fragmentation of habitat,

The analysis and comparison of two route options is summarized in Table 2-8 below.

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NSPML has identified the Southern route option as preferred, in an effort to minimize the environmental impact of the project. The total circuit length for the chosen route is 160 km.

Table 2-8: Line Routing Options for 230-kV Transmission Line

Alternative Means	Technical Feasibility	Economic Comparison	Selected Means
Transmission corridor south of Granite Lake	Considered feasible. The proximity to existing access roads could facilitate access for construction and maintenance activities	Higher cost option due to 20 km increase in route length	Selected means
Transmission corridor north of Granite Lake.	Considered feasible. Shortest distance between Burgeo Highway and Granite Canal, but no existing access to area north of Granite Lake and requires construction of new access road.	Least cost option.	

2.2.14 Other Design Decisions

At various stages during the conduct of the Hatch conceptual and functional design development of the Maritime Link Project, NSPML has adopted conceptual design and facility siting decisions that have influenced the design development. These include decisions related to the design configuration of the ac substations in Newfoundland. While Hatch personnel have made contributions to these decisions, the final decisions in each of these cases was taken by NSPML. Notes regarding these design decisions are provided in the following sections of this report.

2.3 Adopted System Design Concept

There are eight main components of the Maritime Link project:

- In Newfoundland, a new overhead ac transmission line between Granite Canal and Bottom Brook.
- In Newfoundland, new switchyards adjacent/near to the existing Granite Canal and Bottom Brook Substations, to accommodate the new 230-kV ac transmission line and to provide two switched connections for the two converter transformers at Bottom Brook converter station.
- AC/DC converter stations at a new site adjacent to Bottom Brook Substation in Newfoundland, and at a new site adjacent to Woodbine Substation in Cape Breton.
- New shoreline grounding sites with currently preferred sites at St. George’s in Newfoundland and Big Lorraine in Cape Breton, and grounding lines from the converter stations at Bottom Brook and Woodbine to their respective shoreline grounding sites.

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- In Newfoundland, a new overhead HVdc transmission line between Bottom Brook and Cape Ray, and in Cape Breton, a new overhead HVdc transmission line between Point Aconi and Woodbine Substation.
- At Cape Ray in Newfoundland and Point Aconi in Cape Breton, overhead to underground transition compounds to connect the overhead dc transmission lines to the underground cables.
- Two dc cables across the Cabot Strait, including underground cables from the overhead/underground transition compounds to the subsea cable landing sites at the respective shorelines in Newfoundland and Cape Breton, underground/submarine transitions at the subsea cable landing sites near Cape Ray in Newfoundland and Point Aconi in Cape Breton, and submarine cables between the Cape Ray and Point Aconi cable landing sites.
- In Cape Breton, expansion of the Woodbine Substation to accommodate two switched connections for the converter transformers in the Woodbine converter station and additional modifications.

Figure 2-3 shows the entire Maritime Link Project. The HVdc portion of the line is shown in dark red for the overland sections, and in grey for the submarine section. The HVac portion of the line is shown in light red. The grounding lines are shown in blue, and the transition compounds and converter sites are specifically identified.

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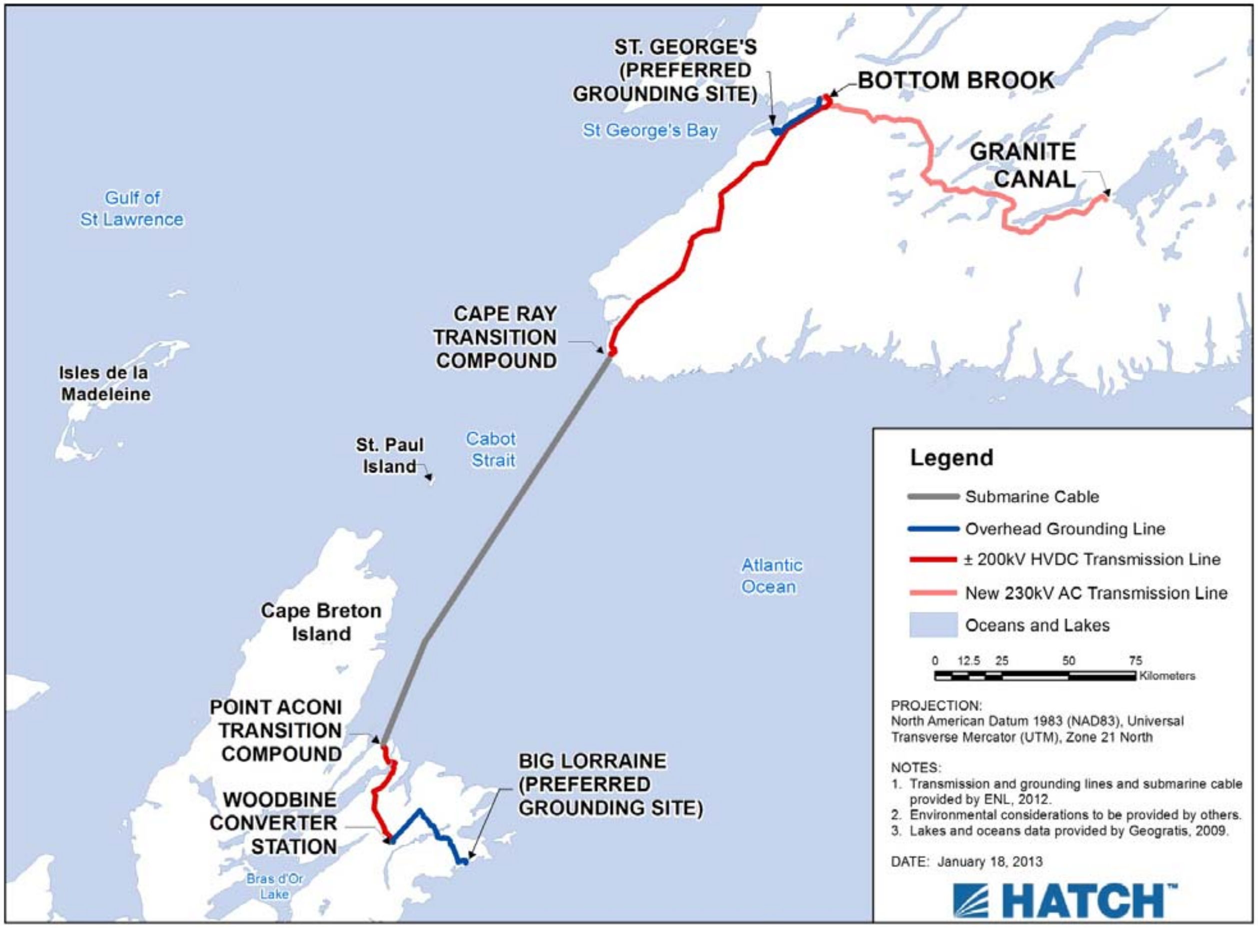

PROJECTION:
North American Datum 1983 (NAD83), Universal Transverse Mercator (UTM), Zone 21 North

NOTES:
1. Transmission and grounding lines and submarine cable provided by ENL, 2012.
2. Environmental considerations to be provided by others.
3. Lakes and oceans data provided by Geogratis, 2009.

DATE: January 18, 2013

Figure 2-3: Overview of Maritime Link Project

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3. Technical Description of Project Elements

The main project elements are described in the following sections, including representation of conceptual design decisions and routing and siting decisions adopted cooperatively between NSPML and Hatch. The description provided herein consists of a continuation of the basic system design decisions described in Section 2 above, and consideration of facility siting and routing undertaken during the Conceptual Basis of Design stage of project development.

3.1 HVdc Line

The HVdc line is comprised of three sections: two overland line sections on the Island of Newfoundland and on Cape Breton, and a subsea section across the Cabot Strait. At the interfaces between the overland sections and the subsea section are transition compounds to connect the overhead transmission conductors to the underground and subsea cables.

3.1.1 Overland Transmission Line

Functional Requirements

The functional requirement for the transmission line is to deliver 250 MW of electric power per pole (equivalent to 1250 A of electrical current per pole) at a dc voltage of +/- 200 kV (400 kV between the poles). The line must be capable of withstanding various ambient conditions of wind, temperature, ice and lightning, to which it may be reasonably subjected during its lifetime.

Line Route

Both the Newfoundland and Nova Scotia segments of the HVdc transmission line are almost entirely located parallel to existing transmission facilities. This not only reduces the environmental impact of the project, but also facilitates construction and maintenance operations due to presence of existing access roads and opportunities to obtain operating synergies through potentially combined patrolling and routine maintenance.

The Newfoundland segment of the HVdc transmission line will be constructed between Bottom Brook converter station and Cape Ray transition compound, with an approximate length of 142 km.

The line is fairly close to the Gulf of St. Lawrence and stays in a valley between the mountains, so for the most part the elevations are fairly low. The highest point on the route is 225 m above sea level, and the lowest point is near sea level.

An overall map view of the proposed route alignment is provided in Figure 3-1 below, with the proposed alignment of the new HVdc overhead line shown as a dark red line.

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The transmission line will exit the converter station at Bottom Brook and travel South. It will cross over 138-kV line TL250 at Burgeo Road and will continue parallel to the TransCanada Highway and 138-kV line TL214 (which comprises guyed aluminum structures). The HVdc line will remain to the East of TL214 and will not cross it. TL214 terminates at Doyles station and beyond that point, the HVdc line will run parallel to 69-kV line TL215. Near the end of the HVdc line, it will not be parallel to any line for a short section and will then terminate at the Cape Ray transition compound.

The terrain comprises generally rolling hills and is dry in this section. The conditions of the soil appear to be fairly good. For most of the route, the HVdc line will be in a valley with mountains on either side. There are three relatively large river crossings.

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Figure 3-1: HVdc Transmission Line Route in Newfoundland

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The HVdc line will be installed in the expanded right-of-way of existing lines. Tree clearing will likely be required for most of the line length.

The Nova Scotia segment of the HVdc transmission line will be constructed between the Point Aconi transition site and the Woodbine converter station, with an approximate length of 47 km, which includes a 1 km underground section at Woodbine station.

The HVdc transmission line will remain parallel to 230-kV line L7015 for most of the length, except for the section between Prince Mine Road and Little Bras d'Or.

For the first half of the line, soil conditions are good and the terrain is fairly flat and easily accessible. The terrain becomes slightly hilly for the remainder of the route, in which the route cuts through thicker trees and the existing roads are spaced further apart.

The highest elevation point is at 185 m and the lowest is at sea level.

There are a few critical pinch points, which will require relatively modest modification to existing transmission lines, to facilitate right-of-way for the HVdc transmission line.

At the Woodbine converter station end, the HVdc line route crosses a number of existing transmission lines. To avoid reliability issues affecting both the HVdc line and the affected ac transmission lines, the final 1, 000 meters of the 47 km line route will be built using dc underground cables direct buried in trenches, and an overhead/underground transition compound will be built at the approach of the HVdc overhead lines to the existing ac transmission corridor.

An overall map view is provided in the following Figure 3-2.

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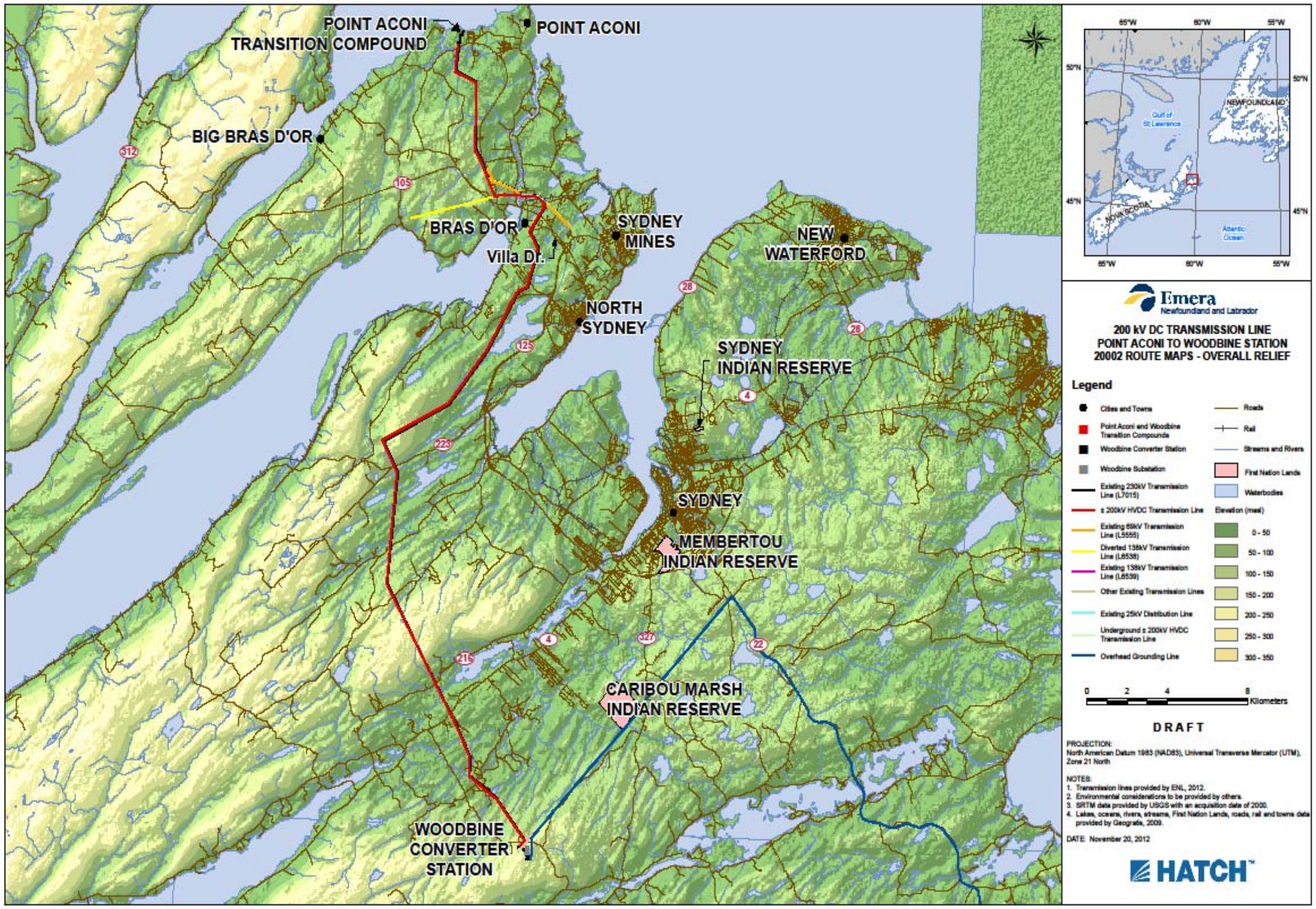

PROJECTION:
North American Datum 1983 (NAD83), Universal Transverse Mercator (UTM), Zone 21 North

NOTES:
1. Transmission lines provided by ENL, 2012.
2. Environmental considerations to be provided by others.
3. SRTM data provided by USGS with an acquisition date of 2000.
4. Lakes, oceans, rivers, streams, First Nation Lands, roads, rail and towns data provided by Geogratis, 2009.

DATE: November 20, 2012

Figure 3-2: HVdc Transmission Line Route in Nova Scotia

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3.1.2 Subsea Cable

Functional requirements

The functional requirement for the subsea transmission cable is to deliver 1250 A of electrical current per pole at dc voltages +200 kV compared to ground on the positive pole, and -200 kV compared to ground on the negative pole. The cable system must provide an assured service life of at least 50 years, under the specified loading conditions and the known operating conditions, and the system must be capable of enduring known exposures to pack ice, marine vessels and anchors, with a return period of 1000 years between externally caused failures of either one of the two poles in the cable system.

Cable Route

The study area for the subsea cable has been selected as the 2000 meter wide corridor presented in Figure 3-3 below. This corridor has been chosen to minimize the crossing distance between Newfoundland and Cape Breton, representing a route length of approximately 170 km from landfall to landfall. The depth of the crossing ranges from sea level to a maximum depth of 470 meters.

At the landfall locations in Cape Ray and Point Aconi, cable transition sites will be established immediately onshore, where the submarine cables will be anchored to shore and spliced to underground cables of identical capacity. The underground cables will be routed on land from the cable anchor sites to the overhead/underground transition sites described in Section 3.1.3 below.

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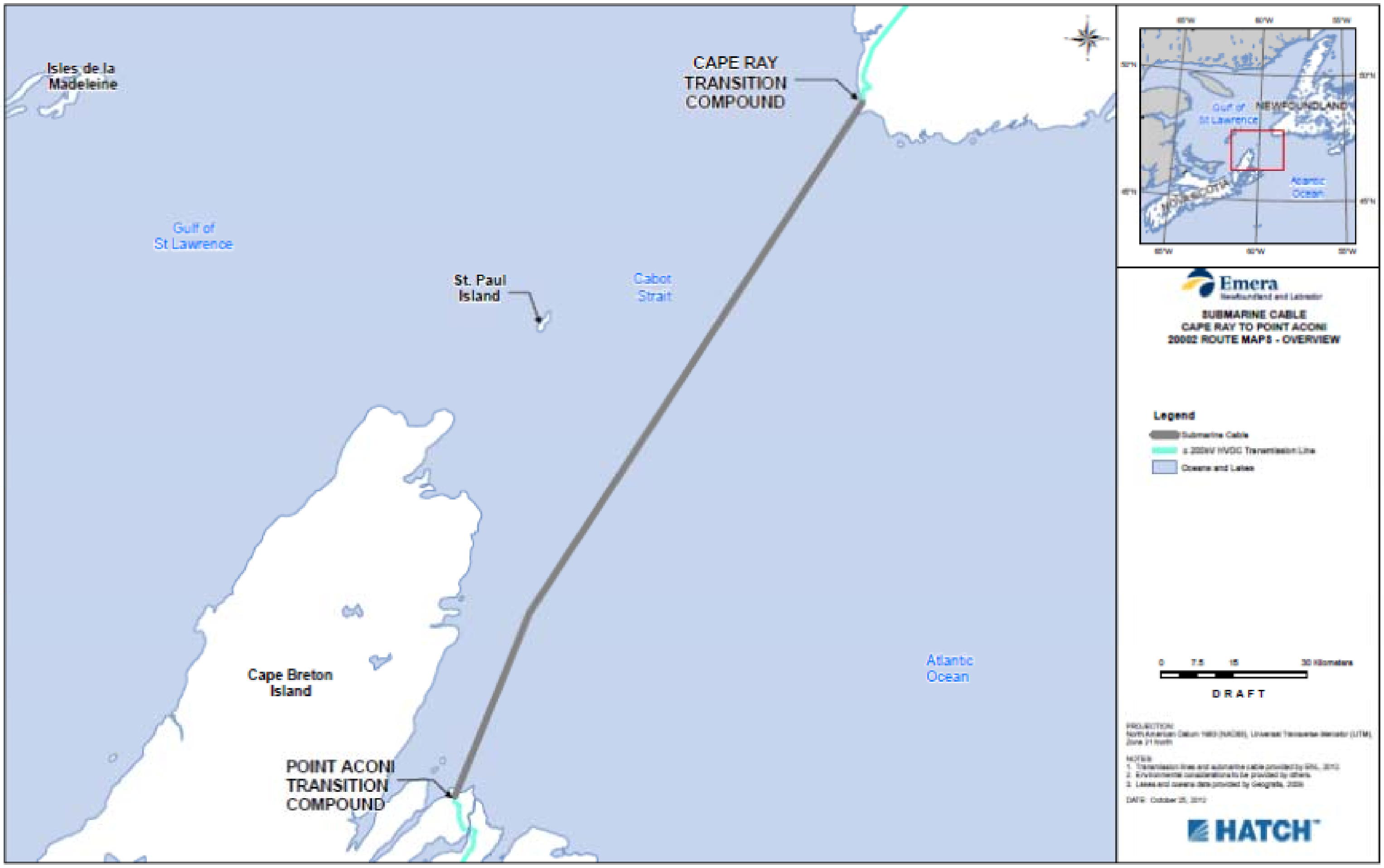

Figure 3-3: Route of Submarine Cable

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3.1.3 Overhead/Underground Transitions

Functional requirements

The subsea cables will be brought ashore near Cape Ray, Newfoundland and Point Aconi, Nova Scotia, connected to underground cables of equivalent capacity, which will be routed to inland transition sites where the underground cables will be connected to the HVdc overhead transmission lines. These sites are called Overhead/Underground Transition Compounds.

The function of the overhead/underground transition compounds is to make a secure and reliable connection between the overhead HVdc transmission lines and the underground/submarine cables, away from the intense salt-spray environment at the seashore. The overhead/underground transition compounds also serve as connection points for various communications, signalling and sensing equipment associated with the underground and submarine cables, including thermal sensing fibres embedded in the underground and submarine cables and optional optical fibres embedded in the cables. Finally, the overhead/underground transition compounds will be used to install the surge arrestors that are used to protect the underground and submarine cables against lightning surges due to lightning strikes on the overhead HVdc transmission lines.

Facility Siting

The site selected for constructing the Overhead/Underground Transition Compounds in Newfoundland is located near Cape Ray, approximately 2 km inland from the Cape Ray cable anchor site. In Cape Breton, the Overhead/Underground Transition Compound will be located near Point Aconi, roughly 1 km inland from the Point Aconi cable anchor site. The general locations of the sites are near the termination points of the submarine cable as shown in Figure 3.3 above. The locations with more details with respect to the shore, other salient features and the general layout have been developed as part of the preliminary engineering.

The transition compounds will be constructed over a grounding grid to ensure safety of utility workers against ground potential rise during a fault condition. The facilities will be completely enclosed and designed such that the maintenance can be carried out all year around.

3.2 AC/DC Converters

Functional Requirements

As stated earlier, the Maritime Link (ML) is being planned to interconnect the Newfoundland and Nova Scotia ac systems using a ± 200-kV, 500 MW transmission link supplied by Voltage Source Converter (VSC) technology. The ac/dc converters will be configured as a dual-monopole system, wherein the two poles operate independently of each other, however, the term “bipolar” is used interchangeably with “dual-monopolar” throughout this document.

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The interconnection points of the HVdc link with the HVac systems in Newfoundland and Nova Scotia are selected to be the existing 230-kV Bottom Brook Substation and 345-kV Woodbine Substation respectively. Two new converter stations will be constructed at these locations. The Converter Station at Bottom Brook will convert the 230-kV ac to ± 200kV dc at the Newfoundland end. Similarly the Converter Station at Woodbine will convert the ± 200kV dc to 345-kV ac at the Nova Scotia end.

Facility Siting

The locations of the two Converter Stations are shown in Figures 3-4 and 3-5 below.

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Figure 3-4: Location of Bottom Brook Converter Station

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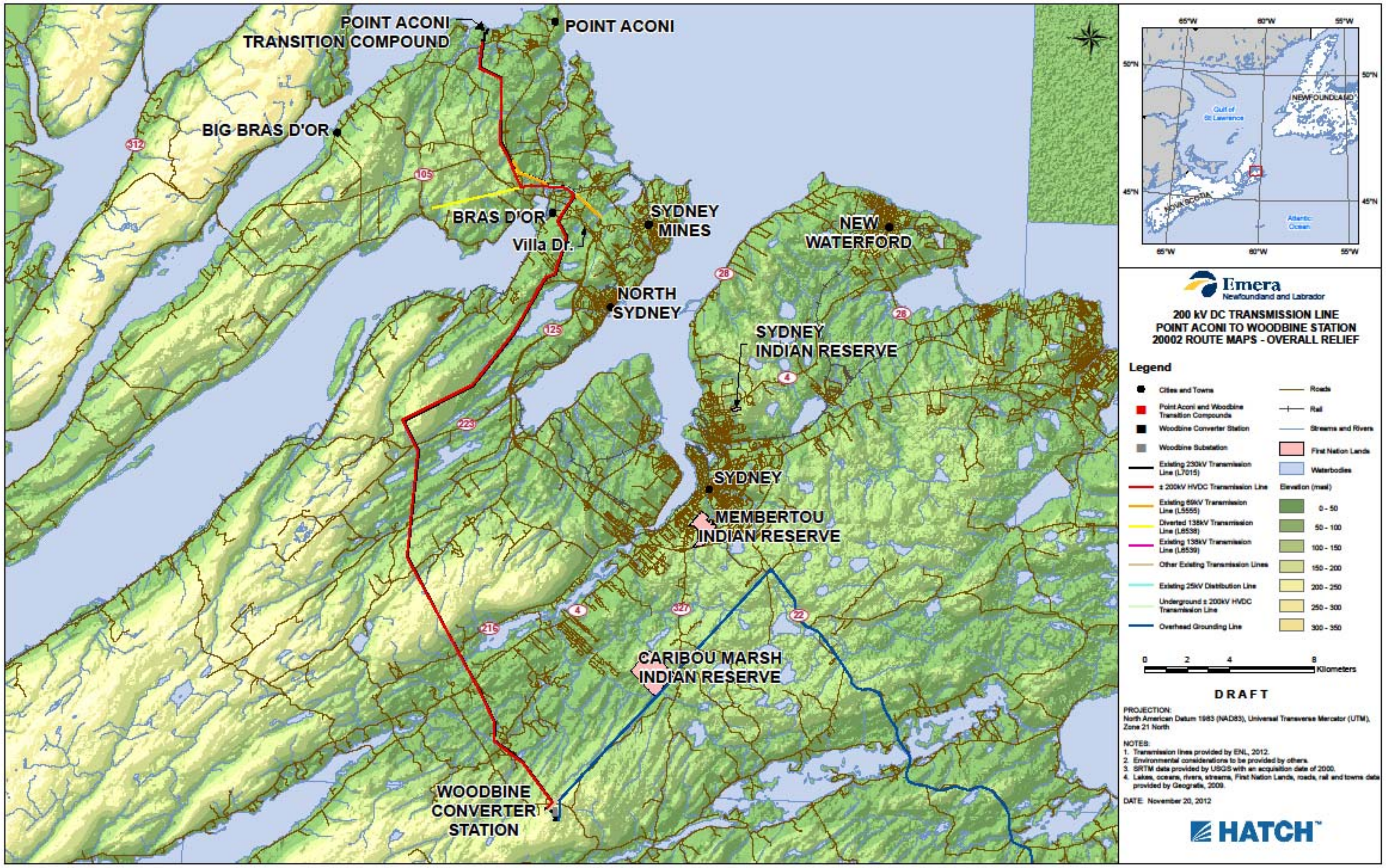

Figure 3-5: Location of Woodbine Converter Station

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The Bottom Brook Converter Station is proposed to be located approximately 350m east of the existing Bottom Brook substation. The site is restricted in development on the east and south sides by an existing silviculture development. The site is also restricted on the north side by an existing transmission line (TL233) that heads to Buchans. The existing site is forested and will require clearing/grubbing of trees and stripping of topsoil to remove organic materials from beneath the proposed works. The access road for the new Converter site will be shared with the new Bottom Brook switchyard and will be connected to the existing gravel access road of the Bottom Brook Substation.

The Woodbine Converter Station site is located to the south of the existing Woodbine Substation. The existing site is forested and will require clearing/grubbing of trees and stripping of topsoil to remove organic materials from beneath the proposed works. The initial site investigations indicate that much of the proposed work may occur in the rock cut on the west edge of the site. A new access road will be required to provide access to the Converter Station.

3.3 Grounding System

3.3.1 Shoreline Grounding Site

Functional Requirements

The grounding sites associated with the converter stations transfer the current from the metallic ground return conductor to earth during normal bipolar, and emergency mono-polar operation.

During bipolar operation of a VSC scheme comprised of two asymmetrical poles, the residual current will flow through the grounding system. The value of residual current is the function of the degree of balance between the poles; for balanced bipolar operation, the value will be less than 1% of rated current.

In addition to providing a continuous path for current imbalance under normal conditions, the grounding sites also provide a temporary earth return path for the full system current during any outage or interruption of a converter pole or its corresponding transmission path. The sites may be used during a pole outage if metallic return is not available. A pole outage is expected to occur for a short duration, expected to be between 40-120 hours per year for the Maritime Link project.

As described in Section 2.2.8 above, NSPML has elected to proceed with earth return rather than metallic return, and NSPML has opted for a shore grounding site rather than a land-based or sea-based grounding site.

Facility Siting – Newfoundland

The currently preferred grounding site associated with the Bottom Brook converter station is located near St. George’s. The selected site ES#7 “St. George’s” and the second choice site ES#2A “Indian Head” are shown in Figure 3-6 below.

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Figure 3-6: Location of Converter Grounding Site – Newfoundland

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This grounding site is located near the St. George's community and the major infrastructure in proximity include Newfoundland Hydro distribution network, a distribution substation, a waste water treatment plant, industrial units and the community buried infrastructure.

Facility Siting – Nova Scotia

The currently preferred grounding site associated with the Woodbine converter station is at "Big Lorraine," located on the north-east shoreline of Cape Breton. The location of this site is shown in Figure 3-7 below. The conceptual design of the site facilities as described in this and subsequent sections is with respect to this site. This site is located in a cove and is fairly remote from any infrastructure. A stream flows into the cove from a pond located adjacent to the cove.

3.3.2 Grounding line

Functional Requirements

The two converter stations at Bottom Brook and Woodbine will be connected to the Grounding Sites by low voltage distribution lines in the range of 5-kV. The insulation level of a grounding line is dependent on the steady state voltage during monopolar operation, transient voltage during transfer of pole current to grounding site (pole blocking), induced voltages from ac or dc lines, and the converter neutral bus insulation design. This voltage is dependent on the design and configuration of the converter stations and will be finalized after selection of the converter station vendor. Generally the lines will be insulated at low voltage (5-kV) and installed on single wood poles. The conductor types will be two sub-conductors of ASC 954 MCM Goldenrod. Surge arrestors will be installed on the conductors at regular intervals, in consultation with the converter station vendor.

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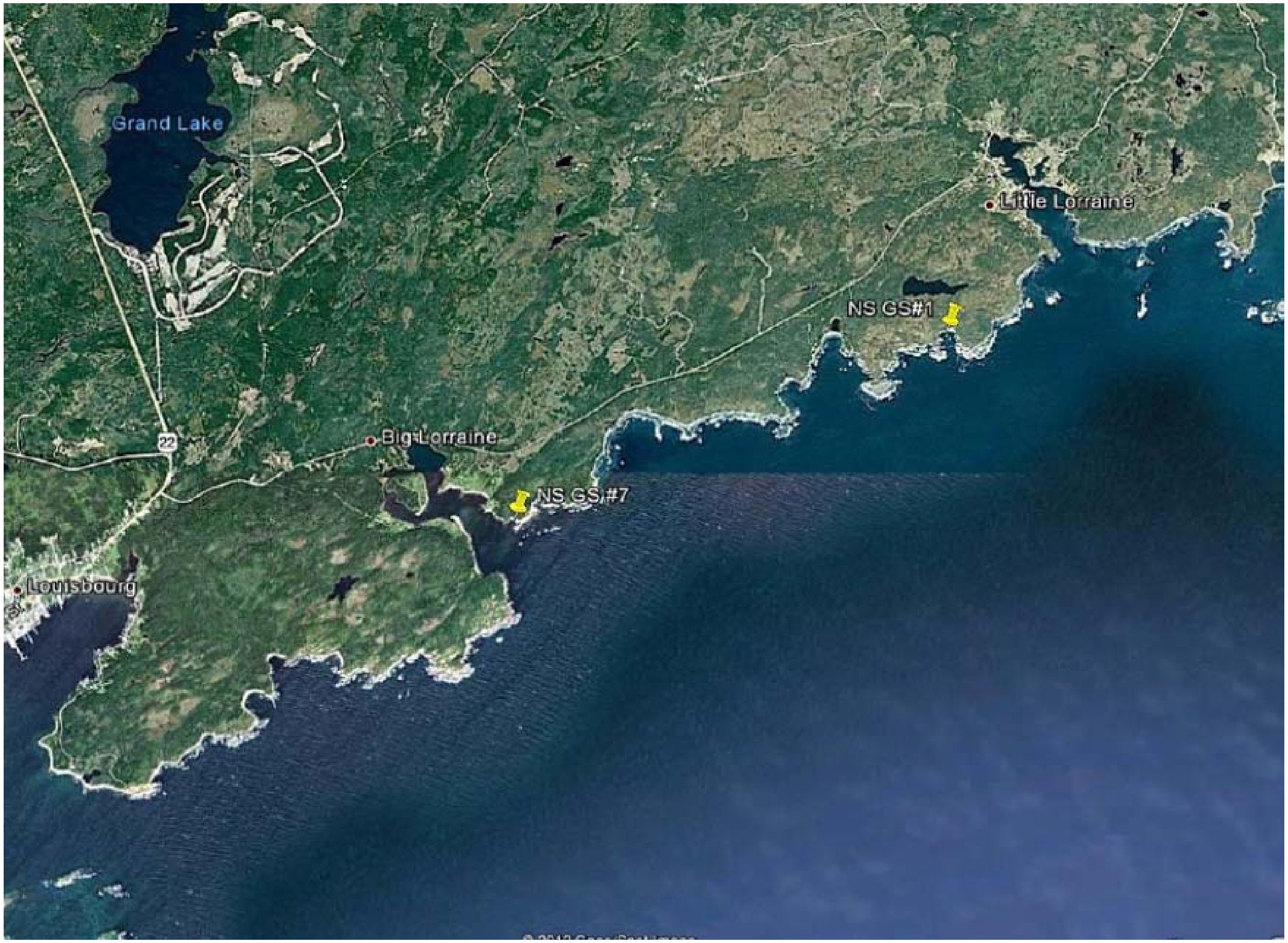

Figure 3-7: Location of Converter Grounding Site – Nova Scotia

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Grounding Line Route – Newfoundland

Fur the currently preferred grounding site at St. George's, the grounding line will originate from Bottom Brook converter station, and will be routed outside the ac line to the Granite Canal station towards the existing TL214 line. Thereafter, the grounding line will remain parallel to TL214 and the HVdc line up to a point close to St George's. The line will then be routed to the grounding site near St George's. The route is indicated in Figure 3-8, with the grounding line shown in blue. The total length of the line is estimated as 28 km.

Grounding Line Route - Nova Scotia

For the currently preferred grounding site at Big Lorraine, the grounding line will originate from Woodbine converter station and travel along the existing transmission lines corridor in the northeast direction. At the intersection of this corridor and Hwy-22 (Louisbourg Hwy), the grounding line will turn in a southeast direction and follow Hwy-22. Shortly before the Big Lorraine grounding site, the grounding line will divert from the Hwy-22 and reach the site. The route is shown in Figure 3-9 below, with the grounding line shown in blue. The circuit length is approximately 47 km.

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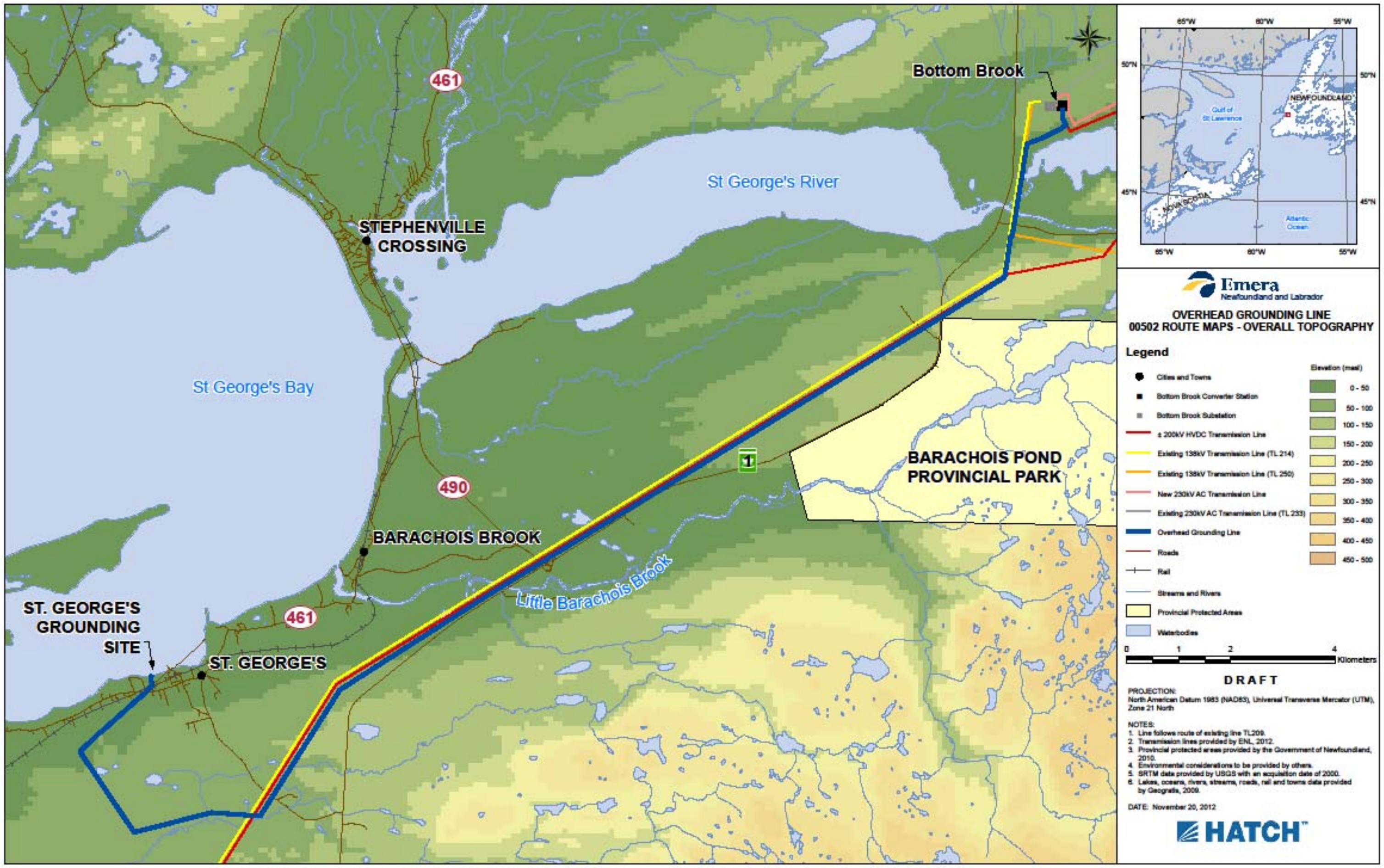

Figure 3-8: Proposed Route of the Grounding Line – Newfoundland

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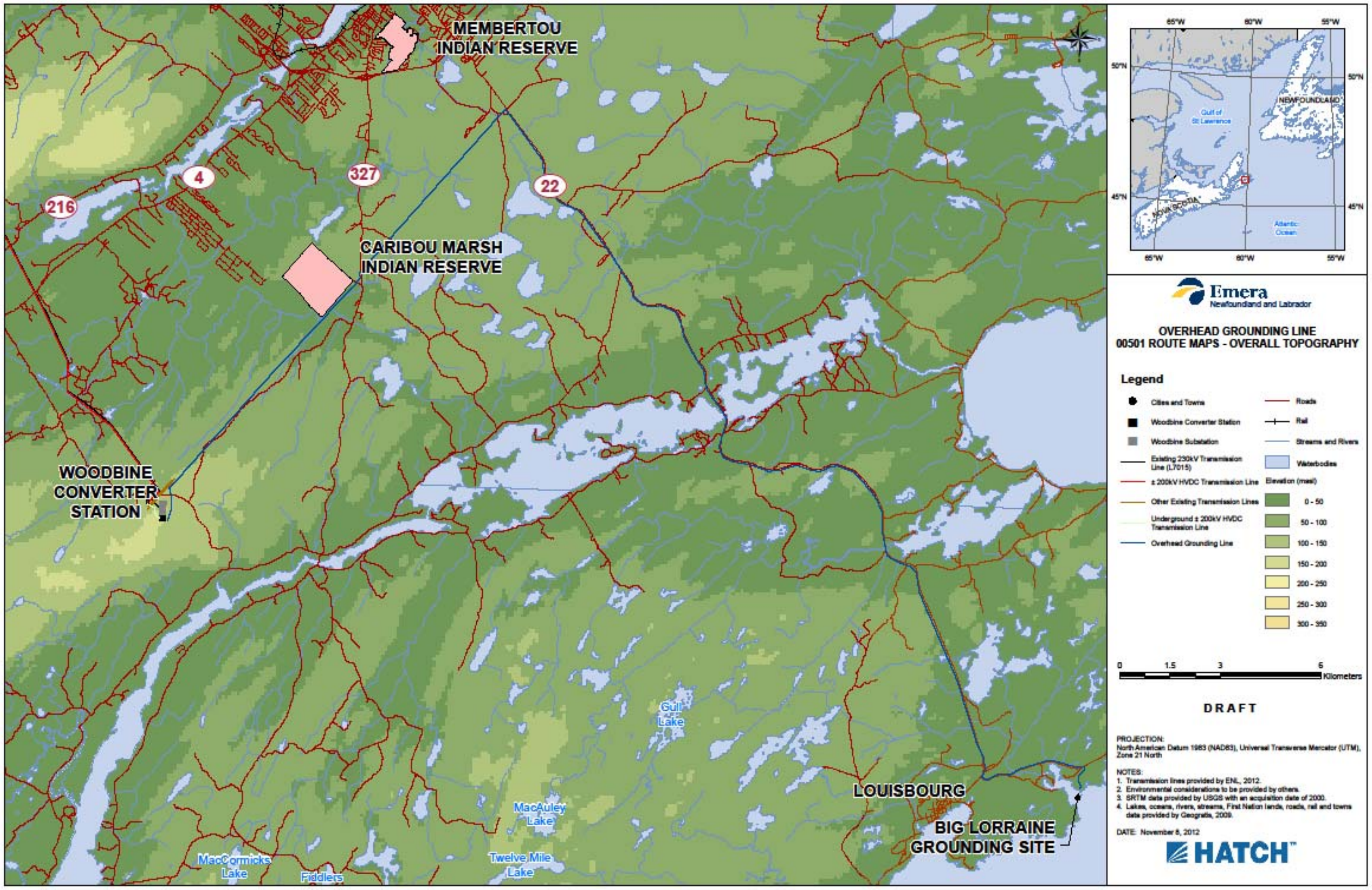

Figure 3-9: Proposed Route of the Grounding Line – Nova Scotia

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3.4 AC System Integration

As indicated in Section 2.2.5 above, the fundamental requirements for ac system integration include substation facilities at Bottom Brook Substation in Newfoundland and Woodbine Substation in Cape Breton, to accommodate the connection of the ac/dc converter stations into the ac system at these locations. In each case, two connections are required, at each site, one for the converter transformer for the positive pole and one for the converter transformer for the negative pole. The converter transformers themselves will be sited in the fenced property for the ac/dc converter stations, but Bottom Brook Substation and Woodbine Substation must be expanded or rebuilt to accommodate these two new connections.

The need for reliable supply into the Bottom Brook converter station dictates the need for a third transmission connection into this station, because Bottom Brook is currently connected to the Newfoundland grid by just two 230-kV circuits: TL211 from Massey Drive, and TL233 from Buchans. In the event of a contingency loss or maintenance outage to either of these 230-kV circuits, there would be insufficient transmission capacity to deliver the 500 MW into Bottom Brook needed for the Maritime Link Project. Planning studies undertaken by NSPML in concert with NALCOR/NLH indicated that a new 230-kV line from Granite Canal Substation to Bottom Brook Substation would ensure that the 500 MW delivery into the Bottom Brook ac/dc converters could be supported under credible outage conditions on the Newfoundland transmission system. In support of this additional requirement, one more line connection will be required at Bottom Brook Substation and one new line connection will be required at Granite Canal Substation. The grounding line will be located in the right-of-way of existing facilities and therefore access roads and tree clearing requirements will be minimal.

3.4.1 230-kV Transmission Line

Voltage Level

A 230-kV ac transmission line will be constructed between the new Granite Canal switchyard station (to be constructed close to the existing station) and the new Bottom Brook switchyard.

Functional Requirements

The line must be capable to withstand, without failure, various ambient conditions of wind, temperature, ice and lightning, to which it may be reasonably subjected to during its lifetime.

Line Route

The transmission line will be constructed between the Granite Canal and Bottom Brook stations, with an approximate length of 160 km. The route, illustrated in Figure 3-10 below, passes over the Long Range Mountains in the middle. The highest point on the route is 455 m above sea level and the lowest point is 6 m below sea level.

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The route can be divided into three segments:

1- Segment-1 (approximately 50 km)

The line route originates from new Granite Canal switchyard and remains parallel to (or in vicinity of) an existing seasonal-access road. The road runs on the south side of the Granite Canal, passes along Burnt Dam and terminates at the water dam located on Victoria Lake. This road is utilized during summer seasons by the maintenance staff at the Granite Canal station and the various water dams.

2- Segment-2 (approximately 40 km)

The line route is not parallel to any existing linear infrastructure. The terrain is generally flat for majority of sections and significant amount of rock is expected. The route crosses the south outlet of the Victoria Lake. A new access road will not be built in this section. Helicopter construction will be utilized where economically more practical, though temporary access roadways would be required for some construction activities.

3- Segment-3 (approximately 70 km)

The line will cross Burgeo Road and then run parallel to the road and the existing 138-kV line TL250, which comprises wood-pole H-framed structures.

After the TL250 crossing, the route generally remains to the south of Burgeo Road. At about 4 km before TransCanada highway, the line will cross over both TL250 and Burgeo Road and head north towards the new Bottom Brook 230-kV station. The last structures outside Bottom Brook station will be double-circuit, shared between the new 230-kV line and existing 230-kV line TL233. This is required to ensure sufficient space for the new switching station and converter station sites.

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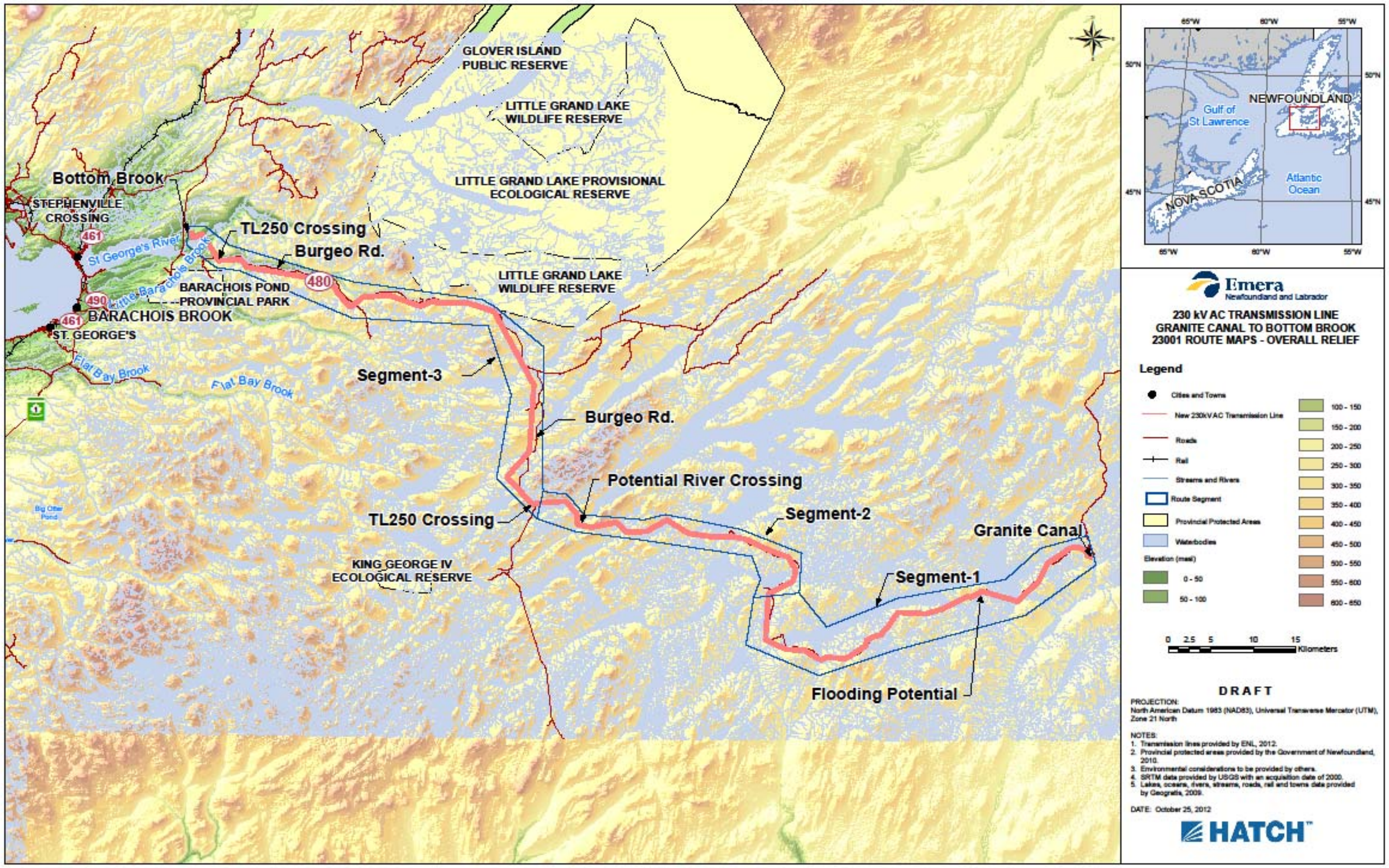

230 kV AC TRANSMISSION LINE
GRANITE CANAL TO BOTTOM BROOK
23001 ROUTE MAPS - OVERALL RELIEF

DRAFT

PROJECTION:
North American Datum 1983 (NAD83), Universal Transverse Mercator (UTM), Zone 21 North

NOTES:
1. Transmission lines provided by ENL, 2012.
2. Provincial protected areas provided by the Government of Newfoundland, 2010.
3. Environmental considerations to be provided by others.
4. SRTM data provided by USGS with an acquisition date of 2000.
5. Lakes, oceans, rivers, streams, roads, rail and towns data provided by Geogratis, 2009.

DATE: October 25, 2012

Figure 3-10: Route of 230-kV Transmission Line

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3.4.2 AC Substation Development – Granite Canal

Voltage Level

The voltage level of the proposed Granite Canal switchyard will be 230 kV, which is the NLH standard HV grid voltage.

Functional Requirements

The functional requirement for the proposed Granite Canal Switchyard is to serve as the source end of the third link between the NLH bulk power system and Bottom Brook Switchyard.

Facility Siting and Configuration

It was originally planned to site the Granite Canal station adjacent to the Granite Canal generating station. When the site was examined, it was found that there was insufficient flat land at the generation site to allow development of a 4-breaker 230-kV station. Thus it was agreed between NSPML and Nalcor to move the switchyard to the nearest suitable site. This was found to be approximately 300 meters from the existing Granite Canal generating station. This site allows the relative ease of connection to the existing Granite Canal to Upper Salmon transmission line. The Upper Salmon station in turn connects to the Bay d'Espoir station, which is a large hydro generating site on the Island of Newfoundland. The site for the proposed Granite Canal Switchyard is adjacent to the road from Millartown to the Granite Canal generating station, which allows a short access route to the proposed site.

Originally it was planned to have the site configured as a single bus with the span from the existing generating station connected to one side of the bus and two lines connected to the other side of the bus. One line connects to Bottom Brook, and the other connects into the previously existing line from Granite Canal generating station to the Upper Salmon substation. A reactor was connected by a breaker to the line to Bottom Brook to keep the line end voltage under control when connecting the line to Bottom Brook at the Granite Canal switchyard. After a review by NSPML and Nalcor, it was decided to change the bus configuration to a ring bus configuration. This modified configuration is designed to provide protection to the reactor during switching operations.

The proposed siting of the Granite Canal station is illustrated in Figure 3-11 below.

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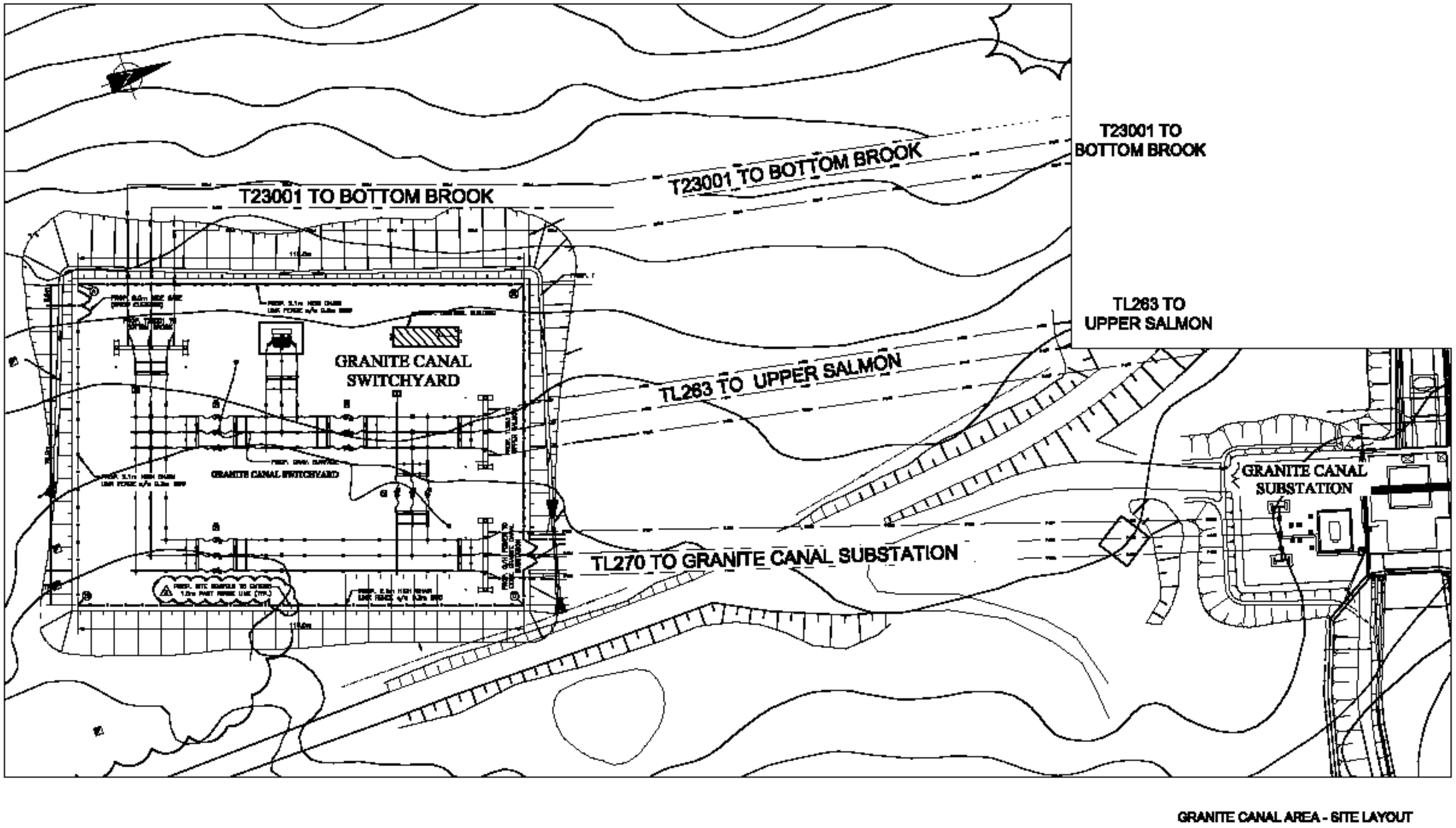

Figure 3-11: Location of New Granite Canal Station

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3.4.3 AC Substation Development – Bottom Brook

Voltage Level

The voltage level of the proposed Bottom Brook switchyard will be 230 kV, which is the NLH standard HV grid voltage.

Functional Requirements

The functional requirement for the Bottom Brook Switchyard is to serve as connection point for two converter transformers located in the nearby Bottom Brook ac/dc converter station, and to serve as the end of the third link between the NLH bulk power system and Bottom Brook area.

Facility Configuration

The existing Bottom Brook substation contains 69-kV, 138-kV and 230-kV facilities. Because the existing 230-kV facility at Bottom Brook would be difficult to expand adequately to reliably provide power to the ac/dc converter, it is proposed to build a new 4-diameter, 12-breaker compact breaker-and-a-half switchyard adjacent on one side to the existing Bottom Brook substation and on the other side to the proposed ac/dc converter station. This configuration was originally conceived of by Nalcor and agreed by NSPML.

The new switchyard will have connections to allow supply to the existing 138-kV facilities at Bottom Brook substation and also to the ac/dc converter transformers. Removal of the existing 230-kV portion of the existing substation will require transfer of the existing lines TL 209, TL 211 and TL 233, which connect to Stephenville, Massey Drive and Buchans respectively to the new 230-kV switchyard.

Facility Siting

It is proposed to site the new Bottom Brook 230-kV switchyard adjacent to the existing Bottom Brook substation to the west and within a few tens of meters to the proposed ac/dc converter station to the east. Access to the site will be off the existing Bottom Brook Substation access road, which in turn connects to the Trans Canada Highway in the Stephenville area. The access road to the proposed new 230-kV switchyard will also be extended to serve the ac/dc converter station. The locations of the new Bottom Brook switchyard is shown in Figure 3-12 below, in the context of the other existing and proposed facilities in the area.

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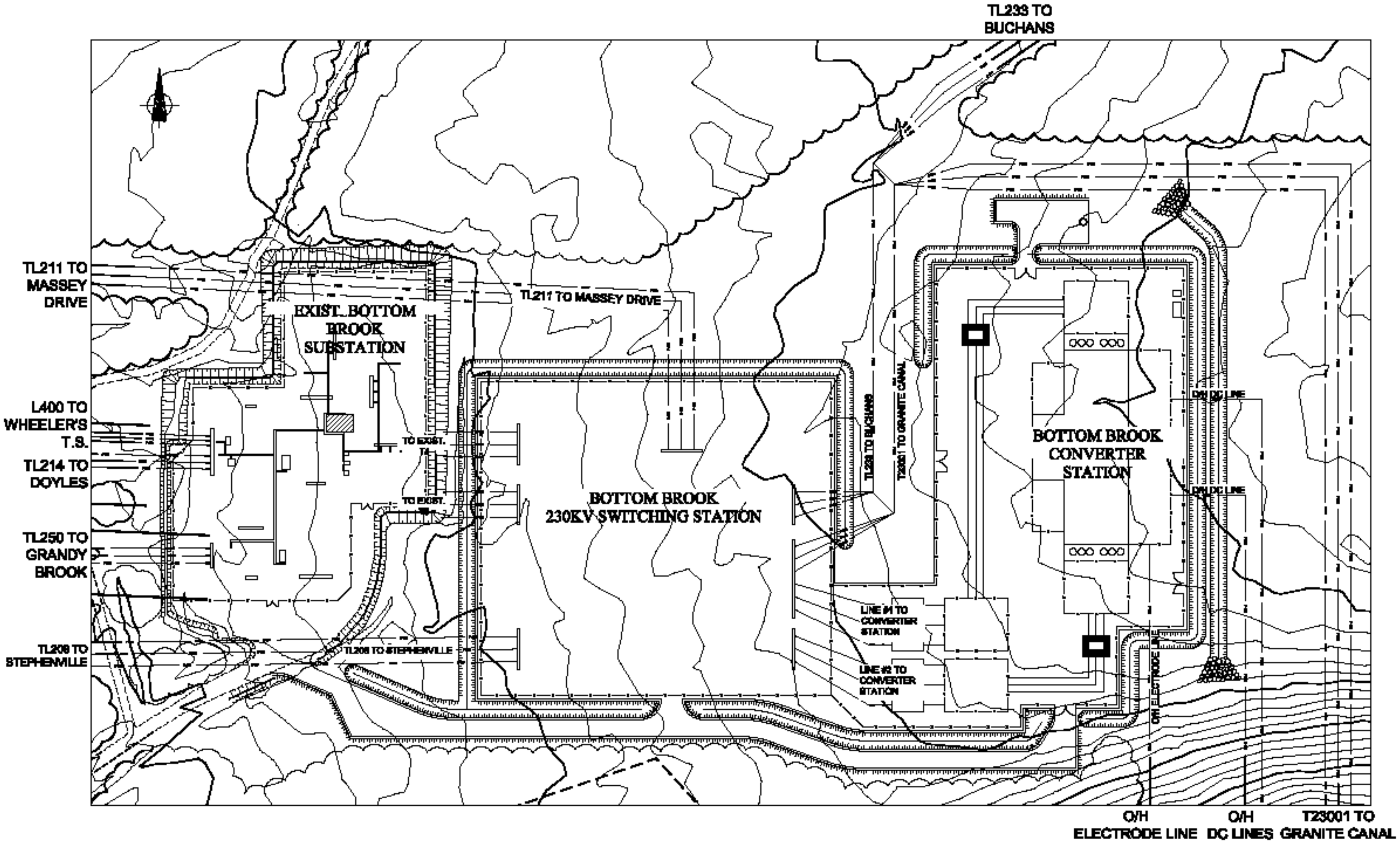

Figure 3-12: Location of New Bottom Brook Station

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3.4.4 AC Substation Development – Woodbine

Voltage Level

The voltage level at the Woodbine substation, which will connect to the Woodbine dc/ac conversion facilities will be 345 kV. The existing 345-kV portion of the substation is presently connected to 230-kV facilities at the station and it is proposed this connection capacity between the two voltage levels will be doubled. The 345-kV and 230-kV voltage levels in the Nova Scotia Power Incorporated (NSPI) system constitute the backbone of the provincial power grid. These voltage levels connect to all major generation and loads in the province.

Functional Requirements

The functional requirement of the Woodbine station is to connect the output of the proposed dc/ac converter at Woodbine to the ac bulk power system in the province. This will enable increased reliability of supply in the province.

Facility Siting

The Woodbine substation is situated in the main power corridor on the eastern end of Cape Breton island, and it has connections to a major coal fired generating station at Lingan to the east. The station is a major hub in the NSPI system and is readily accessible from the island's highway network.

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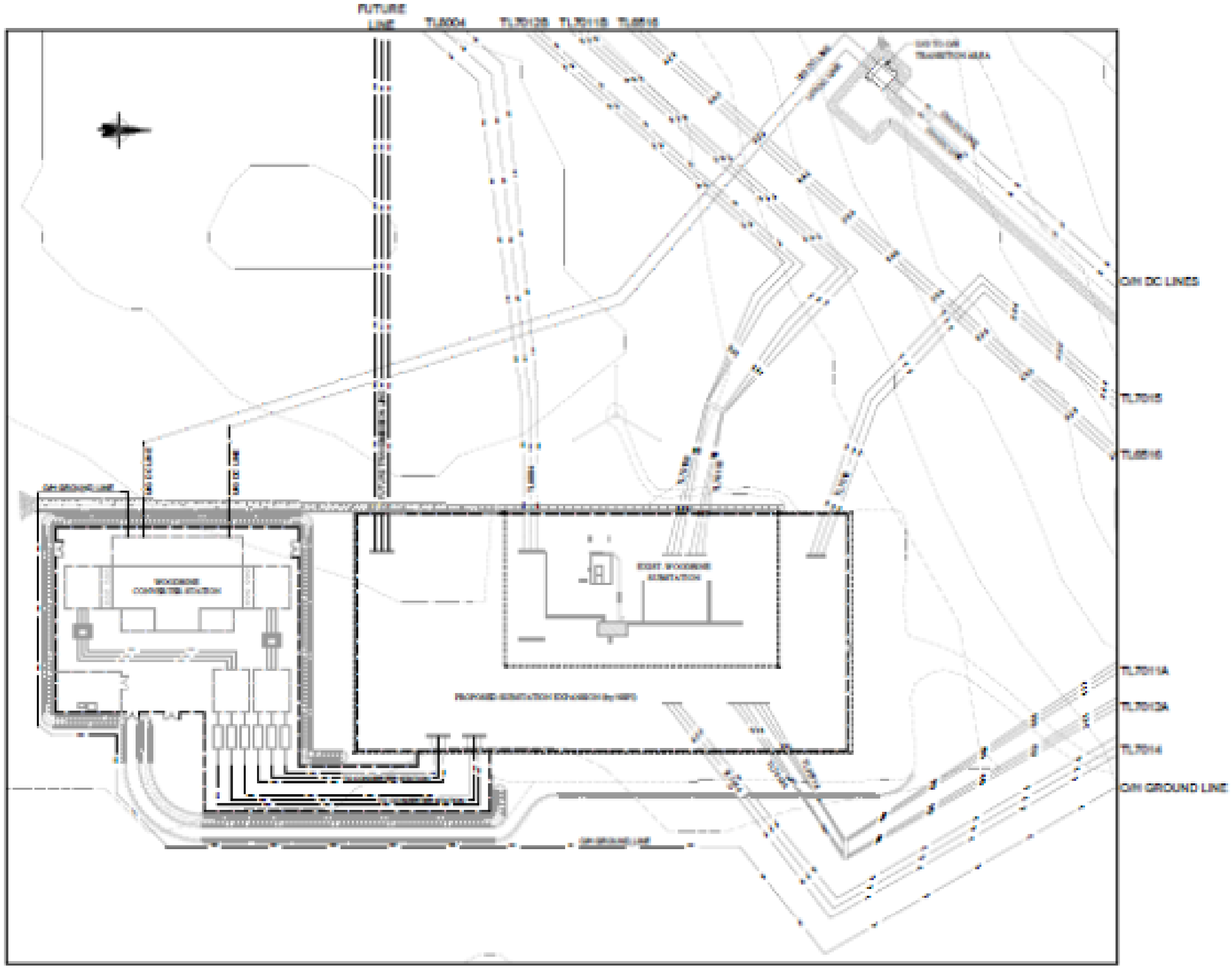

Figure 3-13: Location of Woodbine Substation

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4. Design Review of Project Elements

4.1 Overland HVdc Transmission Line

4.1.1 Design Criteria

The transmission line will be designed in accordance with applicable Canadian (i.e., CSA) standards, applicable specifications (typically IEEE, ASTM) and best industry practices.

Various electrical studies have been performed, based upon best industry practices and NSPML identified parameters to define the electrical characteristics for the HVdc transmission lines. These electrical studies define the insulation and air-gap requirements, shielding requirements, corona and EMF calculations; which have been utilized in the development of line design.

The transmission line will also be designed to withstand the weather events listed in Table 4-1 below.

Table 4-1: Weather Conditions for Design of Transmission Lines

Weather Condition	Radial Ice Mm	Wind Pa	Temp °C	Remarks
CSA Severe	19	400	-20	Ice density = 900 kg/m^3
High wind (CSA)	-	800 (75 mph)	-20	CSA 60826:06 Fig. CA1
High wind	-	1725 (110 mph)	2	Wind speed is advised by NSPML and assumed as 'hourly-average' at 10 m above ground.
High wind (Wreckhouse area only)	-	2225 (125 mph)	2	
Heavy ice (CSA)	50	-	-20	CSA 60826:06 Fig. CA2 and spatial factor of 1.5.
Wind+Ice	25	515 (60 mph)	2	Wind speed is advised by NSPML and assumed as hourly-average at 10 m above ground.

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The minimum vertical clearances will be as follows and checked at maximum conductor operating temperature:

Ground	8.8 m
Roads	11 m [maximum vehicle height = 7.6 m]
Rails	11 m
Navigable waterways	[Based upon Table-3 of CSA and appropriate crossing class]

Conductor Type and Size

Hatch carried out a conductor optimization study to identify the optimum conductor type and size for the project. The study considered three conductors and made the evaluation using different technical and financial/economic parameters including:

Market value of electric energy	$64/MHh in 2017
Escalation of value	3% per year
Cost of capital	9.5% per year
Included term (economic)	50 years
Average loading	316 MW and 790 Amperes per pole

Based on the evaluation, the recommended conductor type is Aluminum Conductor Steel Reinforced (ACSR) 2156 Bluebird.

ACSR conductor type is the predominant conductor type utilized for transmission lines. and it has superior sag/tension performance as compared with ASC (Aluminum Stranded Conductor) which was also considered earlier.

Structure Types/Sizes

Hatch carried out a comparative analysis for various structure types and the following structure types have been selected for the HVdc transmission line:

- All tangent structures in Newfoundland will be Guyed Lattice Steel Towers. The bulk of structures utilized in Newfoundland will be this type.
- All tangent structures in Nova Scotia will be Self-support Lattice Steel Towers.
- All Heavy angle and Dead-end structures will be Self-support Lattice Steel Towers.

The typical guyed lattice steel tower and self-support lattice steel tower are shown in Figures 4.1 and 4.2 respectively.

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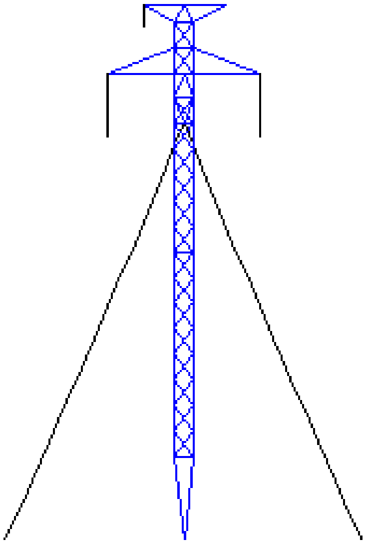

Figure 4-1: Guyed Lattice Steel Tower

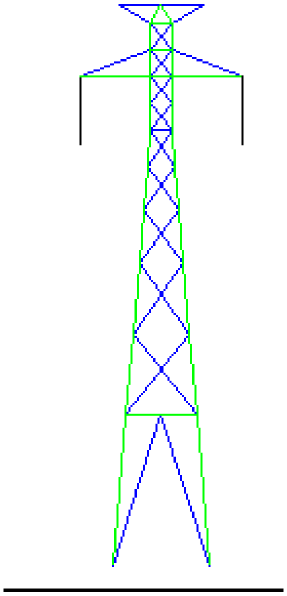

Figure 4-2: Typical Self-support Lattice Steel Tower

4.1.2 Estimated Quantities

The estimated quantities for the Newfoundland segment of the HVdc transmission line are as follows:

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- Line length: 142 km.
- The conductor type is single ACSR 2156 Bluebird per pole; shield-wire type is Alumoweld steel and OPGW (Optical Ground Wire) loose-buffer tube (48-Single mode fibers) surrounded by Alumoweld steel strands. Conductor and shield-wire each include a sag and wastage allowance of 1% and 2% respectively (total 3%). The allowance for OPGW is 10% to allow for sag and wastage allowance as above and additional allowance for the increased lengths required at fiber-splicing structures.
- Total structures: 485 structures including 436 tangents, 5 running angles and 44 dead-ends structures. Additionally, 2 structures on top of the transition compound building are also required.
- Allowance for mitigation to prevent tower rusting in coastal areas is included for a length of 2 km.
- Geotechnical soil investigation is assumed at 4-km intervals along the line length.
- Foundation and anchor quantities have been calculated based upon the following distribution of soil conditions (normal%/rock%/bog%): 65/20/15.
- Access road: New construction and upgrades as required.
- Tree clearing: Estimated total clearing for estimating purposes.
- Insulator strings: The calculated quantities for insulator assemblies are as follows; Suspension-926, Running angle-10, Dead-ends-176, Jumper-88, and 4 strings for transition compound structure. The insulator assemblies will be single-I string for tangent and running angle structures. The dead-end assemblies will be double-strings for safety. The insulators will be porcelain or toughened glass
- Additional insulators to mitigate flashovers due to salt contamination for a line length of 2 km.
- All structures will be individually grounded. A single counterpoise connection is assumed connecting all the structures (excluding road and water crossings).
- Conductor accessories will include suspension cushion grip clamps with armour rods, compression dead-ends, full-tension splices and Stockbridge type vibration dampers.
- Shield-wire accessories include suspension clamps, bolted or compression dead-ends, full-tension splices and Stockbridge or Spiral type vibration dampers.

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- OPGW accessories include suspension clamps (AGS type including neoprene cushion and armour rods for protection), preformed dead-ends, vibration dampers, splice boxes and their attachments and down-leads (at splicing locations). The splice boxes are assumed at approximate intervals of 4-km each.
- Allowance has been made for modification of 138-kV line TL250 at one location for the cross-over of the HVdc line.
- Warning spheres have been added for water crossing(s) where navigation may be expected.
- Other accessories are calculated on a percentile basis.

The estimated quantities for the Nova Scotia segment of the HVdc transmission line are as follows:

- Line length: 46 km (plus 1 km underground at Woodbine station).
- The conductor type is single ACSR 2156 Bluebird per pole; Shield-wire type is Alumoweld steel and OPGW (Optical Ground Wire) loose-buffer tube (48-Single mode fibers) surrounded by Alumoweld steel strands. Conductor and shield-wire each include a sag and wastage allowance of 1% and 2% respectively (total 3%). The allowance for OPGW is 10% to allow for sag and wastage allowance as above and additional allowance for the increased lengths required at fiber-splicing structures.
- Total structures: 172 structures including 139 tangents, 7 running angles and 26 dead-ends. Additionally, 4 strings for transition compound structures are also included in the transmission line estimate.
- Allowance for mitigation measures to protect towers against coastal rust is included for a length of 2 km from the coast.
- Geotechnical soil investigation is assumed at intervals of 4 km along the route length.
- Foundation and anchor quantities have been calculated based upon the following soil conditions (normal% / rock% / bog%); 80/10/10.
- Access road: Estimated total length of road upgrades, for estimating purposes.
- Tree clearing: Estimated total clearing for estimating purposes.
- Insulator strings: The calculated quantities for insulator assemblies are as follows: Suspension-278, Running angle-14, Dead-ends-104, Jumper-52, and 4 strings for transition compound structures. The insulator assemblies will be single-I string for tangent and running angle structures. The dead-end assemblies will be double-strings for safety. The insulators will be porcelain or toughened glass.
- Additional insulators to mitigate flashovers due to salt contamination are included for 2 kms of line length.

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- All structures will be individually grounded. A single counterpoise connection is assumed connecting all the structures (excluding road and water crossings).
- Conductor accessories include suspension cushion clamps with armour rods, compression dead-ends, full-tension splices and Stockbridge type vibration dampers.
- Shield-wire accessories include suspension clamps, bolted or compression dead-ends, full-tension splices and Stockbridge or Spiral type vibration dampers.
- OPGW accessories include suspension clamps (AGS type including neoprene cushion and armour rods for protection), preformed dead-ends, vibration dampers, splice boxes and their attachments and down-leads (at splicing locations). The spice boxes are assumed at approximate intervals of 4-km each.
- Moving of line 3S-403 to the other side of L5555. The works include a new distribution line and dismantling of the old line.
- Possible relocation of L7015 near Villa Drive. The works include installation of new wood structures (4-tangents and 2 dead-ends) and dismantling of existing towers.
- New HVdc underground cables for the two dc poles for approximately 1000 m each near the Woodbine converter station to avoid multiple line crossings is included. The work includes a new fenced compound including, A-frame, cable sealing ends, surge arrestors and their steel support structures. A visual barrier will be installed to prevent vandalism of the terminations.
- Other accessories as calculated on a percentile basis.

4.1.3 Contracting Strategy

The main facets for any infrastructure project are Engineering, Procurement and Construction. The transmission line project can be executed by contracting through any one or combination of the strategies shown in Table 4-2 below.

Table 4-2: Contracting Strategies

Strategy	Owner's engineer	Detailed engineering	Procurement	Construction
EPC	Engineering contractor	EPC contractor		
Supply-build	N/A	Engineering contractor	Supply-build contractor	
Construction only	N/A	Engineering contractor	NSPML or Program manager contractor	Construction contractor

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In addition, the works can be awarded on various basis (or combinations thereof) as follows:

- Time and Material.
- Unit rate.
- Lumpsum.
- As above but with incentives for budget and time.

In addition to the above, the works can be awarded as one large project or various combinations of overhead line components together, with or without the other project components.

Each of the above tasks has various advantages and disadvantages in terms of project costs, financing and risk sharing. NSPML currently plans to implement the overhead HVdc transmission lines using a fixed-price (lump sum) Supply-Build contracting strategy, except for long-lead items which will be directly procured by NSPML.

4.1.4 *Technical Feasibility*

Design and construction of transmission lines are a proven technology and therefore can be considered as technically feasible. As with any design, project and site specific issues will be defined and applied for the completion of an economic and effective design.

4.2 Subsea Cable

4.2.1 *Design Criteria*

The subsea cable will be designed in accordance with applicable Canadian (CSA, CEC, NBC), American (AEIC, ASTM, ASME, NEMA) and international (IEEE, Electra, CIGRE, IEC, DnV, IHO, ITU, ISO, OHSAS) standards and specifications, and best industry practices.

Various electrical studies have been performed, based upon best industry practices and NSPML identified parameters to define the electrical characteristics for the HVdc cable system. These electrical studies define the insulation requirements, which will be used in the development of the cable system design.

The fundamental criteria governing the design of the cable system are the functional requirements, namely the +/- 200 kV operating voltage, the 500 MW transmission requirement for dual-monopolar (bipolar) operation (250 MW for monopolar operation), and the corresponding 1250 Ampere current rating of the cable system. The cable system will also be designed to operate as specified under the following environmental conditions, which have been gathered by NSPML:

Ocean Depth	Up to 470 meters
Ice and Icebergs	Statistical report on probability of occurrence of icebergs and pack ice

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Tides	Statistical data on semi-diurnal tidal variations
Waves	Statistical data on wave direction and amplitude
Wind	Statistical data on wind direction and speed
Seawater characterisics	Statistical data on water salinity and density
Ocean currents	Statistical data on currents by depth
Seawater temperature	Statistical data on water temperature by depth

Given these environmental conditions, the cable system will be designed and installed to meet identified performance criteria.

The bathymetry and geology of the ocean bottom along the cable route are also important factors in the design of the cable system. This information will be gathered by the cable system vendor as part of the cable supply contract.

Cable Type and Size

Two types of cables are traditionally used for submarine dc power transmission: Mass-paper insulated cables and extruded plastic (cross-linked polyethylene) insulated cables.

Mass paper insulated cables use oil-impregnated paper tapes, wrapped around the central core conductor, to provide insulation between the cable conductor and the cable sheath. The specific cable technology used in HVdc applications is termed a Mass Impregnated cable, which is differentiated by the use of high-density Kraft paper impregnated with a high-viscosity mineral oil. This type of cable has been used in HVdc submarine power transmission for almost 100 years, and has been successfully deployed for power transmission projects up to 500 kV dc over route lengths up to 600 km.

Extruded plastic insulated cables are manufactured with polymeric plastic insulation extruded around a central core conductor. Extruded plastic insulation has been utilized for distribution-class cables since the early 1960s, for transmission land cables since the late 1960s, and for transmission submarine cables since 1973. Extruded plastic insulation has gained in popularity at progressively higher transmission voltages due to the lower cost of plastic insulation compared to mass paper insulation. The most common type of polymeric plastic insulation used for HVdc transmission applications is Cross-linked Polyethylene (XLPE) insulation, created by a manufacturing process which cross-links the long molecular chains of Low Density Polyethylene to form a three-dimensional molecular structure. This process results in a polymeric compound which is stable at higher temperatures than either Low Density Polyethylene or Paper Mass insulation. XLPE insulated cables have been used on HVdc transmission projects up to +/- 200 kV and 500 MW.

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The NSPML Request for Proposals invites proponents to offer either Mass Impregnated or XLPE cables for the Maritime Link Project, subject to specific performance metrics. The specifications call for the cables to be supplied with either copper or aluminum core conductors.

Regardless of the decision regarding the type of cable insulation used, specific design parameters have been established. These are summarized below:

- Cables to be single-core design.
- Conductor screen required between core conductor and cable insulation, consisting of semi-conducting material to reduce the electrical stress on the insulation.
- Semi-conducting insulation screen required between cable insulation and the overlying sheath.
- Metallic sheath outside the semi-conducting insulation screen.
- Outside the metallic sheath, an anti-corrosion insulating over-sheath must be extruded over the cable, providing an overall “jacket” for the cable.
- Overall cable armour required, suitable to provide protection to the cable during installation.
- Outer serving required outside the cable armour, to provide abrasion resistance during cable installation activities.
- Cables to be supplied with embedded fibre optics for a length of several km away from the shore landing, for purposes of Digital Temperature Sensing (DTS) system. As an option, the vendors are also being asked to provide quotations for provision of 48 optical fibres embedded within the cable for communication purposes, throughout the length of the underground and subsea cables.

Installation Technique

Installation techniques for the subsea cable have been deferred to the successful turnkey contractor for the cable supply contract, but installation methods are an important determinant of the future performance of the cable system, particularly the reliability performance. Various installation considerations are presented below, with discussion of the performance implications associated with each factor.

Submarine cables must be installed using specially equipped cable ocean-going laying ships. These ships are outfitted with large rotating turntables where the cable is wound, and specialized submersible machinery for construction activities on the ocean floor.

Several environmental factors affect the reliability performance of submarine cable facilities, and there are various installation methods used to ensure adequate reliability performance in these conditions.

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Some common risk factors for damage to subsea cables include fishery operations, snags by ship anchors and scouring of the ocean bottom by pack ice. All of these exposures are greatest at ocean depths less than 100 m, but risks from ship anchors persist at greater depths.

Common methods of addressing these risks include the design of the cable itself, including the armouring provided on the cable, and various installation techniques. Cable armouring provides adequate protection for most fishery operations, but suitable installation techniques are necessary to provide adequate protection for pack ice scouring and anchor snags.

Common installation methods used for cable reliability enhancement include the following:

- Trenching the cable into the ocean bottom, using hydraulic or mechanical trenching methods.
- Use of native or imported fill materials, and cable “mattresses,” to provide durable and protective cover above the cable.
- Installation of the cable in drilled casings at a suitable depth below the ocean bottom.
- Physical separation of the two cables in a dual-monopolar (bipolar) cable installation by a sufficient distance on the ocean bottom (where practical) to provide reduced risk of a single event damaging both cables.

Use of drilled casings is generally only considered in the final approach to a cable landing, where the risk exposure is greatest. For the majority of the route length of a cable installation, the other three installation techniques are the principal means of ensuring protection of cable against damage.

NSPML has considered all of these installation techniques as suitable for use on the Maritime Link cable system, but has deferred decisions on these matters to the selected supply contractor.

4.2.2 *Estimated Quantities*

The estimated submarine cable length is 360 km (2 runs of 180 km each). For the underground cable from the land/sea cable transition sites to the overhead/underground transition compounds, the estimated cable length is 4 km (2 runs of 1 km each, at each of two coastal transition areas). The EPC contractor is also responsible for supply and installation of terminations within transition compounds, and other ancillary equipment, including:

- Supply and installation of four cable terminations and ancillary equipment for termination of cable in transition compound.
- Four termination support stands to allow mounting of termination in transition compound.
- Surge arresters as required at terminations.

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- Four land-submarine cable transition joints, and splicing of submarine cables to land cables.
- Cable armour anchors and transition bays.
- Submarine cable joints, as required.
- Land cable joints, as required.
- Cathodic protection equipment, as required.
- Fibre optic Digital Temperature Sensing (DTS) system equipment.
- Breakout and termination of fibre optics, complete with DTS unit, in transition compound. Installation of all accessories and supply of ancillary equipment required for cable and DTS fibre optic termination, and
- Installation of interface between surge arresters and overhead transmission lines, including a suitable mounting arrangement for surge arrestors.
- All installation aids, accessories and ancillary equipment required to perform the work.

Additional spare equipment mandated by the Request for Proposal document includes:

- Five thousand (5000) meters submarine cable, continuous length on turntable/carousel.
- Six hundred (600) meters land cable on transportable reel.
- Two terminations.
- Two surge arrestors.
- Four submarine cable joint kits.
- Two transition joint kits.
- Four land cable joint kits.
- One cable armor anchor & transition bay.
- One DTS unit.
- Four cable end cap kits.
- Four submarine cable pulling eye kits.

4.2.3 *Contracting Strategy*

The full cable system, including the submarine cable from Cape Ray to Point Aconi, the cable anchoring and splicing at the landfall cable anchor sites, and the underground cable to the overhead/underground transition sites up to the cable riser terminations, will be procured under a fixed-price (lump sum) design-supply-install (EPC) contract. The lightning arrestors installed at the overhead/underground transition sites at Cape Ray and Point Aconi will also be part of the

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scope of supply for this contract, since these lightning arrestors are supplied to protect the cable system.

The Request for Proposals has been issued for this contract, and bids have been received by NSPML. The RFP identifies the standards governing the installation, and provides functional and performance specifications for the cable system, and makes the proponents responsible for all design, supply and construction decisions to meet these specifications.

4.2.4 Technical Feasibility

HVdc cable systems have been built in subsea cable applications for many years, and the technology is well established. Mass Impregnated cables have been used for many years at voltages, power levels, lengths and ocean depths much greater than those contemplated for the Maritime Link Project, and this technology has a very long and successful track record for these types of projects. Extruded plastic cables, on the other hand, have achieved successful implementation at these voltage and power levels fairly recently, but are rapidly becoming the cable technology of choice at progressively higher voltages and power levels because of the economic advantages of these cables.
At the 170 km length of the NS Power Maritime Link submarine cable, and the +/- 200 kV cable voltage, NSPML project planners have concluded that either insulation technology is technically feasible and proven to deliver reliable service.

4.3 Overhead/underground Transitions

4.3.1 Design Criteria

The transition sites will be completely enclosed as salt-spray could cause contamination to outdoor insulators. The design of the vertical roof bushing, which is exposed to salt spray, would require adequate consideration to avoid flashovers. The final design of the transition compounds will be determined after award of the submarine cable contract as the selected HVdc Cable Supply Contractor will have specific requirements. The clearances in the Transition Building will be determined once the insulation levels are known.

Access to the Transition Building's roof will be incorporated into the design for maintenance of the external, vertical roof bushing. Care will need to be taken in the selection of the roof bushing type. A porcelain or silicon bushing type will likely be selected.

A current example of use of roof bushings is the dc submarine cable project in New Zealand. The cable termination station in the North Island is exposed to extreme pollution. TransPower have used porcelain and silicon roof bushings for this project. Initially the transition station was an outdoor station, and the porcelain housings of the cable terminations were washed every 15 minutes. After enclosing the station and modifying the roof bushing types, the bushings are now washed 2 to 3 times annually. New Zealand's TransPower have had the best operational experience using an HTV silicon bushing type. The roof bushings have been subject to intensive monitoring and regular cleaning. Regular corona inspections are performed on the roof bushings to determine the location and intensity of local discharge activities using specialized cameras.

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For the Maritime Link project, concerns about salt accumulation on the termination bushings has given rise to two optional methods of addressing the risk of flashovers. One option being considered is the application of a salt monitoring system for the termination bushings, and deployment of maintenance forces to wash the bushings when accumulations reach critical levels. To date, no commercially proven system has been identified to fulfill this monitoring activity. A second option being considered is to upgrade the insulation level of the termination bushings, and to install permanent insulator washing facilities to undertake routine cleaning of the insulators during spring, summer and fall seasons.

The roof will include a tower-type structure to permit connection of the roof bushing to the HVdc transmission line without significant stresses on the vertical roof bushing. Provision to bring in the optical fiber cable into the building and the communication terminals has been considered. It is assumed that the cable will be supplied up to the Transition Building in trenches.

The building design will ensure that it will be possible to access all electrical equipment in the Transition Building, with the exception of the cable bushing. The Transition Building will be designed to have positive pressure to ensure contaminants do not enter the building. The internal temperature of the building will be controlled to ensure levels are met.

The site will meet NERC requirements for exterior building security including security fencing. The transition compounds will be unmanned. Maintenance personnel will be at the station only when necessary (washing insulators, repairing cables, maintenance, etc.), and operating personnel will visit the station during regular site inspection/monitoring visits.

Facility Arrangements

A conceptual transition site design, including a conceptual electrical single line diagram, is shown in Figure 4-3. All switches in the transition compound will require interlocking.

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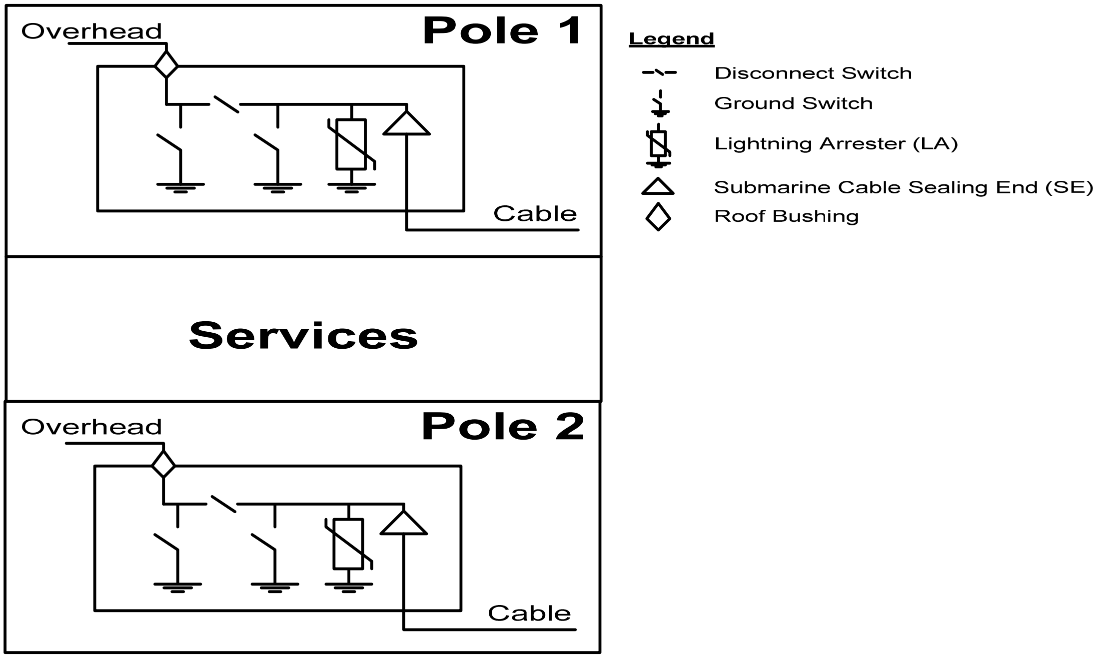

Figure 4-3: Conceptual Transition Station - SLD

The preliminary arrangement of the electrical equipment at the transition compound is shown in Figure 4-4. The exact equipment, size, and clearances will be determined after discussions with the cable and converter equipment suppliers.

The drawing shows the overhead transmission line “dead-end” at the structure on the Transition Building roof, which is also connected to the roof bushing. There is then a connection to the disconnect switch, which requires ground switches on either side. Connection is then made to the surge arrester, and finally to the cable sealing end (cable pothead). The underground cable is connected to the cable sealing end.

The provision will also be required to lift the porcelain cable sealing end (cable pothead) over the completed cable end with stress cone during original installation and maintenance. This requirement implies that a removable hatch in the roof above the cable pothead will be required, meaning that no other equipment can be mounted on the roof.

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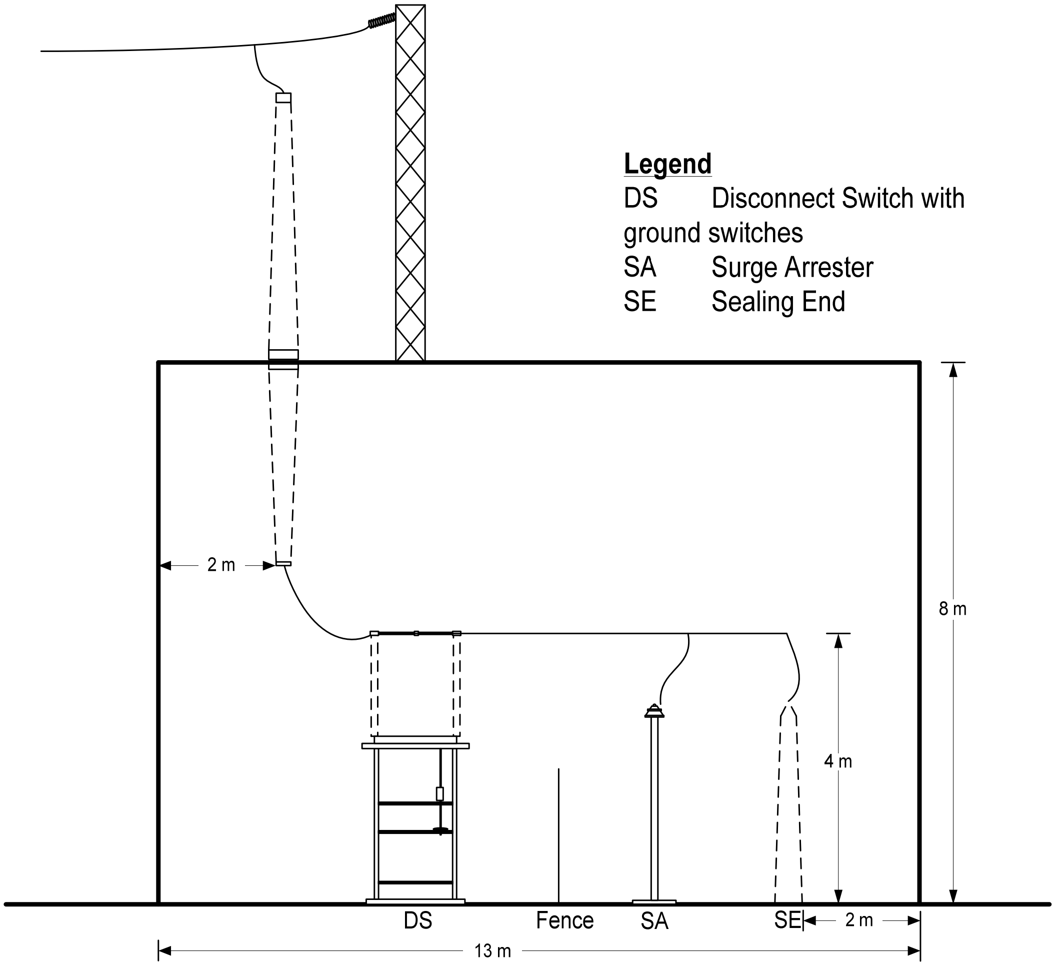

Figure 4-4: Transition Site - Preliminary Electrical Equipment Layout

4.3.2 Estimated Quantities

The transition compounds will include the following major equipment:

- Line dead-end structures.
- Surge arresters not included – part of cable supply contract.
- Cable potheads (dry type) not included – part of cable supply contract.
- Disconnect switches.
- Current transformers.
- Fibre optic communications interface.
- Vertical roof bushing (dry type).

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4.3.3 *Contracting Strategy*

The overhead to underground transition compound facilities at Cape Ray and Point Aconi will be procured under a fixed price supply-install contract. The lightning arrestors installed at the transition sites will be part of the scope of supply for the submarine/underground cable contract, since these lightning arrestors are supplied to protect the cable system. The terminations of the Digital Temperature Sensing (DTS) system, and the installation of the DTS in the control building at the transition compound, will also be part of the submarine/underground cable contract, but the design of the transition compound and building will make provisions for these installations.

4.3.4 *Technical Feasibility*

The technology for connection of overhead lines to underground cables is well established, at voltage levels well above those planned for the Maritime Link Project, and no new or innovative technologies are required to facilitate these transition compounds.

The project specific requirements for the Maritime Link project to be considered in the detailed design will include provisions to address the salt contamination on the insulators and the specific weather conditions as described above. The distance of the transition compounds from the sea shore, 1 km inland in the case of Cape Breton and 2 km inland in the case of Newfoundland, will aid in the prevention of salt contamination buildup. However, some consideration must be given during the detail design stage to ensure that the designs and operating and maintenance practices will adequately address these concerns.

4.4 AC/DC Converters

4.4.1 *Design Criteria*

The requirements and the design criteria for the Converter Stations are being finalized. The HVdc facilities at the converter stations and transition yards shall be designed, manufactured and constructed to achieve the specified ratings over an expected project lifetime of 50 years. The Contractor shall select equipment and building materials accordingly and shall provide sufficient margins in equipment design and select equipment maximum hot spot temperatures to meet these objectives. The Contractor may include additional margins above the values included in equipment standards based on his experience.

The environmental data for the converter stations is provided in the Table 4-3 below.

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Table 4-3: Environmental Conditions for Design of Converter Stations

Description	Unit	Bottom Brook	Woodbine
Ambient temperatures:			
Maximum ambient temperature	Deg C	30	40
Minimum	Deg C	-35	-35
Maximum wet bulb and coincident dry bulb	Deg C		
Maximum temperature for power transfer and reactive output ratings guarantees	Deg C	30	30
Average temperature for design life calculation	Deg C	20	20
Rainfall			
Annual	mm	1400	1200
Maximum in 1 hour	mm	30	>25
Maximum in 24 hour period	mm	170	140
Maximum monthly period	mm	180	150
Lightning			
Keraunic level	days/year	10	10
Average no of Lightning	strokes/sq km/year	0.35	0.35
Seismic	G	0.1	0.1
Pollution Levels			
IEC pollution classification		Heavy	Heavy
Design ESDD level	mg/sq.cm	TBD	TBD
Design NSDD level	mg/sq.cm	TBD	TBD
Cable Transition Station Pollution levels		Cape Ray	Point Aconi
IEC pollution classification		Heavy	Heavy
Design ESDD level	mg/sq.cm	TBD	TBD
Design NSDD level	mg/sq.cm	TBD	TBD

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Operating Modes

The equipment shall be capable of operation in the following operating modes:

- Bipolar (Dual Monopolar) Mode: This will be the normal mode of operation. In this mode the system could be operating in balanced or unbalanced modes with unequal current or voltage in the poles. Any residual unbalance current will flow through the earth/sea return path via the shore electrodes.
- Monopolar Ground Return Mode: In this mode the operating converter will be connected to its own overhead line conductor and submarine cable or to that of the blocked pole.
- Monopolar Metallic Return Mode: This operating mode will be used for emergency conditions only, e.g. a simultaneous outage of a converter pole and one ground connection. In this mode the converter will be connected to its pole conductor and the current will return through the pole conductor of the out of service converter.
- Reduced Voltage Mode: The system shall be designed for continuous operation with HVdc voltage reduced to 70 % nominal in either or both poles. Continuous operation shall be possible anywhere between 100% and 70% of the nominal dc voltage. Reduced voltage shall be available in any of the above operating modes.

Configuration and Ratings

- General Requirements
  - The VSC HVdc transmission system shall be configured as two asymmetric monopoles arranged in a bipolar configuration with equal power transfer capability in both poles in both directions for all continuous and short time ratings.
  - The specified power transfer and reactive power output ratings and all performance criteria shall be achieved for the normal continuous range of converter ac bus voltage and normal continuous and short-time frequency variation for all operating conditions and shall be available under all specified short circuit level conditions and all specified ambient temperature conditions with all redundant cooling equipment out of service.
- Continuous Ratings
  - The system shall have the guaranteed continuous power transfer ratings, shown in Table 4.4, defined at the ac terminals of the sending end station. Symmetrical capability is required for both directions of power transfer.

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Table 4-4: Required Nominal Continuous Ratings

Operating Mode	Nominal DC Voltage (kV)	Nominal DC Current (A)	Guaranteed Power Transfer (MW)	Guaranteed Reactive Output (Mvar)
Bipole (Dual Monopole)	± 200kV	1250	500	250
Monopolar Ground Return	+ 200kV or -200 kV	1250	250	125
Monopolar Metallic Return	200	1250	250 (Note 1)	Note 2
Bipolar Reduced Voltage (70% both poles)	± 140	1250	Note 3	Note 2
Monopolar Reduced Voltage Ground Return (70% voltage)	140	1250	Note 3	Note 2

Notes:
1. Minus losses in the second pole conductor.
2. To be stated by supplier, along with details of reactive and real power capability
3. Supplier to provide a curve of power transfer capability as a function of dc voltage

- Overload Power Transfer and Reactive Output Ratings
    - No requirement for additional short-term or continuous overload capability, other than the inherent capability available due to redundant cooling equipment and ambient temperatures below specified values
    - control features and thermal image models necessary to fully utilize the inherent overload capability of the equipment for real and reactive output with and without redundant cooling shall be provided and enabled for transformers, submarine cables, converter valves and other major equipment

System Performance Requirements

The complete functional and performance requirements of the HVdc system have not yet been finalized. However, preliminary specifications have been prepared in the following areas, which have been used to solicit vendor budget quotations:

- Robust low voltage ride-through performance
- Capability to withstand frequency excursions

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- Robust ride-through for single-phase trip and reclose and three-phase trip and reclose on the ac systems
- Robust performance in ac high voltage scenarios
- Fast recovery following ac system faults
- Automatic dc line fault clearing and power restoration after clearing dc line pole faults
- Fault location and differentiation between overhead line and submarine cable faults
- High reliability in terms of pole forced outage, bipolar forced outage and scheduled and forced energy unavailability
- Power modulation and damping controls –enhanced damping of power oscillations in Nova Scotia, coordination with controls on the Labrador Island Link (LIL) converters
- Frequency stabilization controls – enhanced stabilization of the frequencies on the Island of Newfoundland and in Nova Scotia
- Runback Controls
- Reliable performance of fault recovery, power damping modulations and frequency stabilization with and without communications systems in service
- Automatic AGC control
- Expert System for Operational Hunting

Additional details of the performance requirements are being developed and will be included in the functional specifications. All specified performance requirements will apply regardless of whether only one or both monopoles are in operation. Performance requirements and controller functionality shall also be maintained during reduced voltage operation and for both directions of power flow.

Reliability Requirements

The HVdc system shall be designed for high levels of reliability and energy availability. The HVdc system includes overhead line sections on both sides of the cable that may be subject to flashover leading to increased component exposure to short circuit currents and possibly higher failure rates than with a cable system.

The design shall take into account this exposure to short circuit currents during dc line faults. Sufficient margins and redundant components shall be incorporated in the valves to ensure that faults on the dc line do not result a requirement to perform unscheduled maintenance on the valves in either pole prior to the scheduled maintenance outage.

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The target reliability performance levels for the HVdc system have been developed, addressing the following categories of reliability performance:

- Maximum number of pole forced outages per year per pole
- Maximum number of bipole forced outages per year
- Maximum forced energy unavailability
- Maximum scheduled energy unavailability
- Minimum duration between scheduled pole maintenance outages

The converter supplier will be required to guarantee the forced outage rates and energy unavailability resulting from failures of the supplier's equipment and the performance will be monitored for three years after commercial operation. The requirement to operate at reduced voltage due to the failure of the line to withstand full voltage will not be considered as an outage of as a source of unavailability when evaluating performance. If the guaranteed values are not met then mitigation measures to improve performance will be required.

Facility Arrangements

The arrangement of the HVdc system is shown in the Figure 4-6 below.

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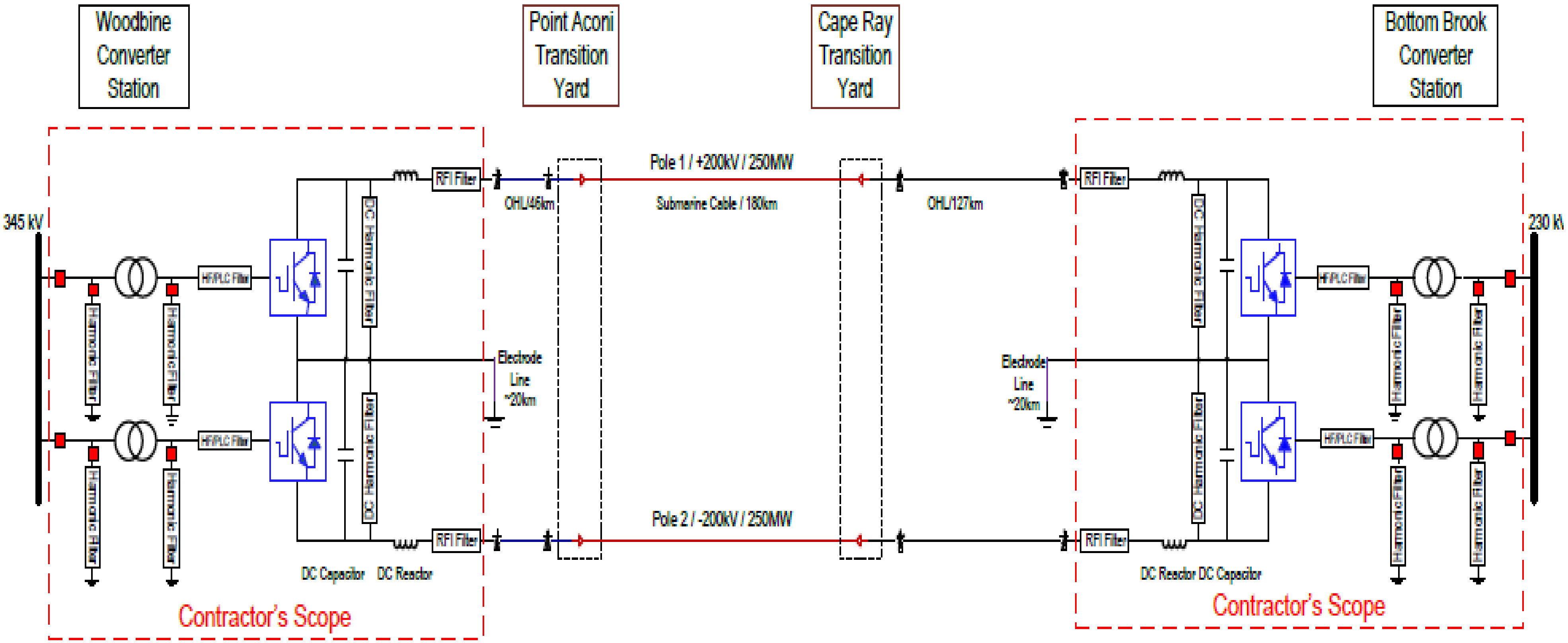

Figure 4-6: Conceptual Single Line Diagram of the VSC based Maritime Link

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The Converter Stations are shown in dotted red lines as Contractor’s scope. The dc side switches required for grounding, maintenance isolation and metallic return switching at the converter stations are not shown. Similarly the disconnects, ground switches, coupling devices, communication interface equipment, protection equipment at both cable transition sites etc are also not shown. These are being developed as part of the ongoing engineering work of the project.

4.4.2 Newfoundland Converter Requirements

Site Arrangements

The Bottom Brook converter station site is proposed to be developed to the east of the existing Bottom Brook substation. The proposed overall site layout has been developed as part of conceptual engineering and will be finalized after the selection of the supplier to meet any specific requirements. Generally the site is restricted in development on the east and south sides by an existing silviculture development. The site is also restricted on the north side by an existing transmission line (TL233) that heads to Buchans. To the west, the new Bottom Brook substation is proposed to be constructed between the converter site and the existing Bottom Brook substation.

The existing site is forested and will require clearing/grubbing of trees and stripping of topsoil to remove organic materials from beneath the proposed works. The existing site drains from east to west with an average cross fall slope of 4%.

The access road for the new converter site will be shared with the new Bottom Brook switchyard site, and total length has been evaluated for estimating purposes.

No existing connection for water and sewer services is available to the site. Water supply for the site will come from a drilled well. Fire water supply will be stored on-site in two above-ground storage tanks, and a diesel fire pump will be housed in a separate ancillary building. The site will be serviced with a looped fire-water piping system that will supply water to six yard hydrants. Sewage will be gravity fed to a septic tank. Effluent from the tank will be treated in an underground sewage dispersion field. Emergency back-up power will also be included through a pad-mounted generator.

Rip-rap drainage ditches will collect storm water from the site and access road and discharge the collected water to a storm-water management pond. The pond will be shared with the Bottom Brook substation site and will be used to control the post-development peak.

An interceptor ditch will be constructed on the east side of the converter site to intercept incoming “clean” water trying to enter the site from the east. The water will be discharged through rock dispersion aprons. Intercepting and redirecting the incoming “clean” water will allow the internal storm-water collection/treatment system at the site to be smaller and less costly.

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Site security will be provided through a 2100-mm high chain link fence. Access to the site will be through manually operated swing gates. Swing gates will also be located around the site for snow clearing and removal operations.

The Converter Building will house the VSC valves and associated equipment, control rooms, offices and maintenance area. The building will be subdivided into three structurally independent buildings: Valve Hall – Pole 1, an Administration/Control/ Maintenance (A/C/M) Building and a Valve Hall – Pole 2. The buildings will be separated by 3-hr fire-rated masonry walls with fire-rated personnel doors and fire-rated rollup doors. Access between buildings will be at the ground level only.

Estimated Quantities

The Bottom Brook converter site development footprint has been sized to include:

- Converter building;
- Space for truck movements;
- Parking (12 spaces);
- Four ac filtering yards;
- One dc equipment yard;
- Two cooling yards;
- Two three pole ac circuit breakers;
- Two transformers;
- Two reactor yards;
- Overhead bus bars; and,
- Other civil infrastructure including ditching, fencing, underground services, etc.

4.4.3 Nova Scotia Converter Requirements

Site Arrangements

The Woodbine converter station site is proposed to be located slightly south of the existing Woodbine substation. The arrangement will be generally similar to the Bottom Brook Converter Station. The existing site is forested and will require clearing/grubbing of trees and stripping of topsoil to remove organic materials from beneath the proposed works. From an initial site investigation, it is expected that much of the proposed work may occur in a rock cut on the west edge of the development, as the existing substation was built in a rock cut along the west and south perimeters. The existing site drains from the northwest to the southeast with an average cross fall slope of 3%.

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A new gravel access road will provide access to the new converter station site. The road will extend to the existing NSPI access road.

No existing connection for water and sewer services is available to the site. Water supply for the site will come from a drilled well. Fire water supply will be stored on-site in two above-ground storage tanks, and a diesel fire pump will be housed in a separate ancillary building. The site will be serviced with a looped fire-water piping system. Sewage will be gravity fed to a septic tank. Effluent from the tank will be treated in an underground sewage dispersion field. Emergency back-up power will also be included through a pad-mounted generator.

Rip-rap drainage ditches will collect storm water from the site and access road and discharge the collected water to a storm-water management pond. Outlet works from the pond will include a new culvert pipe that will discharge stormwater to the existing forested area via a rip-rap dispersion apron, as well as an emergency overflow spillway.

Site security will be provided through a 2100-mm high chain link fence. Access to the site will be through manually-operated swing gates. Swing gates will also be located around the site for snow clearing and removal operations.

Estimated Quantities

The Woodbine converter site development footprint has been quantified for estimating purposes. The arrangement and the equipment will generally be similar to the Bottom Brook Converter Station except for the converter transformer voltage, which shall be 345-kV on the ac side. The converter station shall comprise:

- Converter building;
- Space for truck movements;
- Parking (12 spaces);
- Four ac filtering yards;
- One dc equipment yard;
- Two cooling yards;
- Two three pole ac circuit breakers;
- Two transformers;
- Two reactor yards;
- Overhead bus bars; and,
- Other civil infrastructure including ditching, fencing, underground services, etc.

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4.4.4 *Contracting Strategy*

The converter stations and associated facilities will be procured under a fixed price design-supply-install (EPC) contract because of the specialized nature of the equipment.

4.4.5 *Technical Feasibility*

The design of HVdc systems based on VSC technology are specialized systems offered by a few suppliers. The technical feasibility of such systems is well proven because of systems in operation and a large number in different stages of development and execution. Because of specialized design, the suppliers of these systems will be required to guarantee the performance and reliability per requirements stated above.

4.5 Grounding System

4.5.1 *Design Criteria and Requirements*

The grounding site design shall meet the operating requirements of the HVdc scheme and have negligible impact on the surrounding infrastructure and environment. Also the site installations shall meet the local and national electrical codes, and design shall adhere to the best industry practices. The design criteria for the grounding sites associated with the Converter Station for the Maritime Link Project have been developed and are summarized as follows.

Grounding Site Type

As discussed in the earlier sections 2 and 3, the type of grounding sites selected for the Maritime link Project is shore grounding because of geological and physical conditions of Newfoundland and the northern part of Nova Scotia.

The Bottom Brook and Woodbine converter stations have a continuous current rating of 1250 A (250 MW at 200-kV system voltage) in monopolar operation. A continuous overload capability or short duration overload capability is not foreseen for the monopolar operation and the grounding site will be sized for continuous operation at rated current.

In general terms, grounding site duties will be based on the anticipated pole outage rates which result in the need for monopolar operation of the HVdc system, along with the load factors and planned operating modes of the HVdc transmission system. Preliminary design duties were calculated based on the specified earth return currents, and conservative estimates of pole outages and load factors. Conservative assumptions were adopted regarding HVdc system modes of operation.

The preliminary duties of both grounding sites for the Bottom Brook and Woodbine converter stations have been estimated based on the following parameters:

- The maximum continuous current rating is 1250A.
- The time period for determining permissible loss of material from electrolytic corrosion for surrounding infrastructure caused by grounding site operation is assumed to be 50 years.

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The pole outages for the HVdc system are based on the reliability criteria specified for the Converter Stations. The requirement calls for five pole forced outages and one scheduled outage per annum. The duration of forced outages are considered in accordance with published reliability and availability data of other scheme which are mainly LCC schemes. A two day per year schedule outage on a pole is assumed. The system needs to be designed to meet the reliability requirements including overhead line, cable system, HVdc converters and associated ac system equipment. The duration of scheduled outage may change depending on the maintenance procedures required by the converter supplier.

The grounding site design and its impact on infrastructure has not been evaluated in conceptual phase. The breakwater design and impact assessment will be completed during subsequent stages of design to meet the requirements of the project.

A very conservative mode of operation for the HVdc link was considered to establish the grounding site duties. The grounding site duty will be reviewed in the design stage based on additional data: vendor data for converter stations, equipment failure rates and bipolar imbalances; future system reliability and availability studies; maintenance practices; and planned modes of operation.

The published data on area soil and sea water salinity and temperature were not reviewed during the conceptual design stage to interpret the resistivities of various electrical paths, and will be completed in subsequent design stages.

The safety of a grounding site design is determined from the step potentials at the maximum rated current and the touch potentials on exposed parts at maximum current on land, and voltage gradients in the water. An asymmetric-pole VSC-based HVdc scheme also requires consideration of transient conditions during an HVdc transmission line ground fault to evaluate safety concerns that may result from the higher earth current. The data is not presently available, and the studies are ongoing based on HVdc transmission line fault clearing time and fault levels. The criteria for grounding sites is not based on the elimination of potential gradients, but on the prevention of annoyance to a person or animal subject to the voltage. The tolerable step potentials on the land for a standing or walking human, a prone human and an animal are have been established based on accepted industry norms, and the detailed design of grounding facilities will be completed to ensure that these criteria are met.

The sensitivity to an electric field in water varies for different species and depends on several factors: the size and weight of the animal; the body shape and electrical resistance; the resistivity of the water; the type of current; and the electric field configuration. The tolerable electrical field gradients have been established based on industry norms, and the detailed design of the grounding sites will be completed to ensure that these criteria are met.

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Grounding Element Type and Configuration

The grounding site at each location can operate either as a cathode or an anode. Therefore grounding elements shall be suitable for reversible operation. The number of grounding elements and arrangement in a subsection must allow the contingency of one subsection for maintenance and inspection during operation at rated duty.

The current density of elements will be selected such that it is lower than the vendor recommended density and allows continuous operation of the grounding site for the expected longest duration of outage (i.e., loss of submarine cable in Cabot Strait). The grounding line protection requiring protection equipment at the grounding site has also been considered. This requires reliable dc supply with auxiliary backup and a controlled environment at the grounding sites.

4.5.2 Facility Arrangements – Newfoundland

The grounding element arrangement and the monitoring requirements are based on a high level analysis performed as part of this study, and conservative assumptions regarding grounding facility monitoring practices

The grounding site associated with the Bottom Brook converter station is located near the St. George’s community, and the major infrastructure in proximity include a Newfoundland Power distribution network, one distribution substation, a waste water treatment plant, the area telephone system, along with bridges, industrial plants, and the buried municipal infrastructure.

The electrical facilities at the grounding site will include an array of tubular, High-Silicon Chromium Chill Cast Iron (HSCI) grounding elements arranged in the shoreline pond along the side of the breakwater. The elements will be divided into five subsections, as shown in Figure 4.7 below. Considering a total grounding line current of 1250 A, a current dissipation of 27.78 A per element for normal operation (less than manufacturer’s recommended current value of 54 A and electrode consumption time period of more than three years) and a contingency of one subsection (for maintenance), the grounding site will require 45 elements (i.e., 5 subsections of 9 elements each).

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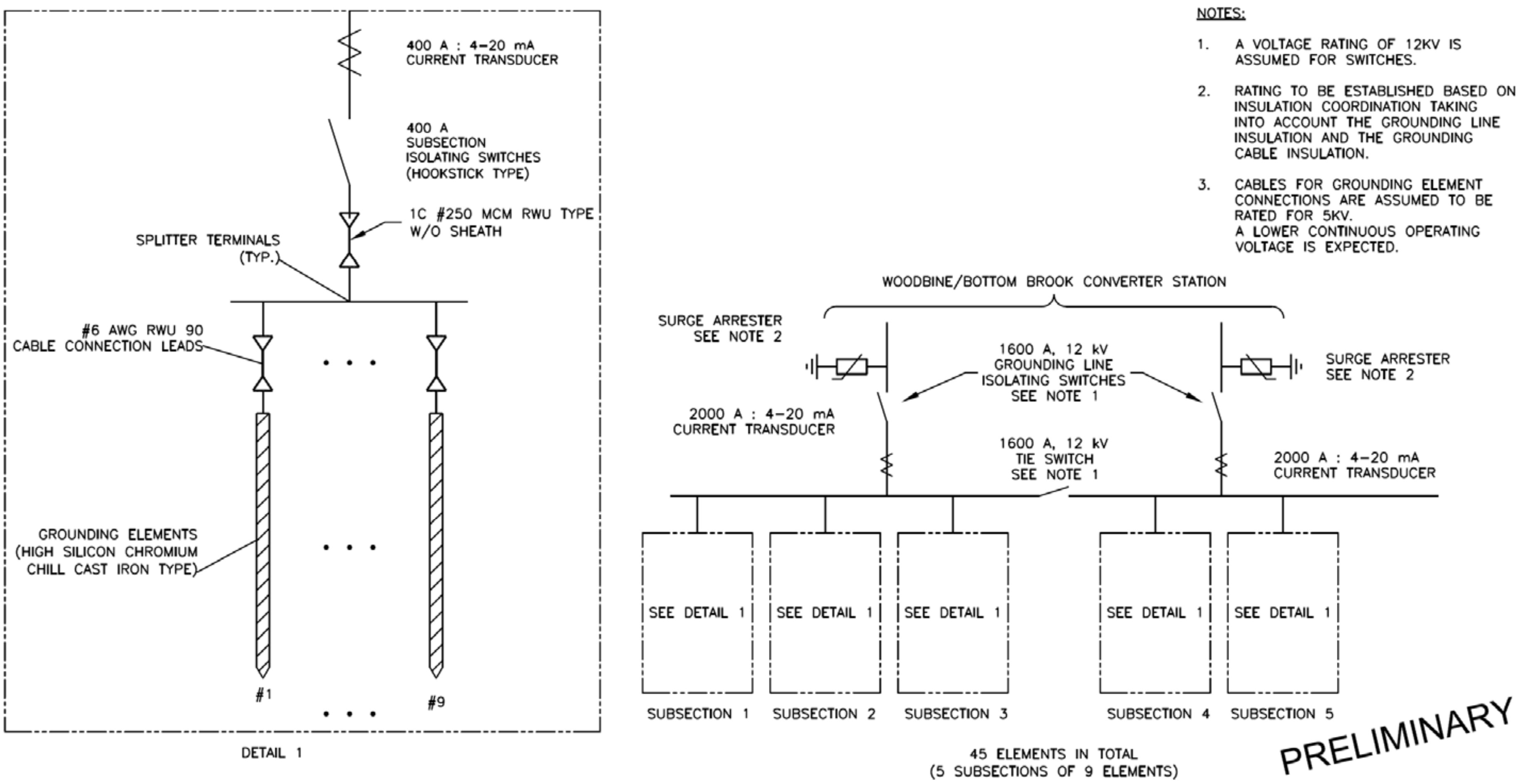

NOTES:

1. A VOLTAGE RATING OF 12KV IS ASSUMED FOR SWITCHES.
2. RATING TO BE ESTABLISHED BASED ON INSULATION COORDINATION TAKING INTO ACCOUNT THE GROUNDING LINE INSULATION AND THE GROUNDING CABLE INSULATION.
3. CABLES FOR GROUNDING ELEMENT CONNECTIONS ARE ASSUMED TO BE RATED FOR 5KV. A LOWER CONTINUOUS OPERATING VOLTAGE IS EXPECTED.

Figure 4-7: General Arrangement of Grounding Site

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The main grounding line conductor switches and tie switch at the grounding site will be motor operated and are required for isolation of the ground element installations from the grounding line and for reconfiguration of the grounding facility. Individual sections will be provided with hook-stick operated switches to facilitate inspection and maintenance of the ground elements. Distribution class surge arresters at the grounding line termination points will be required to protect the grounding site cables and instruments from transient and lightning surges. The surge arrester rating will be a function of the grounding line insulation, the voltage rating of the cables and the voltage ratings of the equipment, and the surge arrester rating will need to be determined as part of the grounding line insulation coordination study. These switches and surge arrester will be arranged on the grounding line dead-end gantry.

Cables rated for 5-kV system voltage are considered from the grounding line to the splitter terminals near the grounding elements; one cable per subsection is considered. The splitter terminals will allow connections to the grounding elements. A typical grounding element is provided with a lead, and the length of the lead can be specified for termination to the splitter terminal. However for this study, splicing of the lead integral to a grounding element with a site-supplied lead is considered.

In normal operation, the two line switches will be closed, and the tie switch will be open. If a neutral-line fault is detected on one grounding line conductor, the switches will be operated to isolate the faulted conductor. The hook-stick operated switches are operated manually to isolate a subsection for maintenance and inspection.

Site Plan

Assuming a discharge of 100% of the earth current into the sea through the breakwater, the dimensions of the breakwater required to ensure a safe gradient of less than 1.25 V/m at the interface of the breakwater and the sea can be calculated. The required contact area of the breakwater with sea body of water is approximately 300 m^2, which translates into a breakwater approaching 83 m in length. The pond side toe of the breakwater will be located to have a 2-m depth at low tide.

Auxiliaries and Monitoring

Remote monitoring, grounding line instrumentation and protection, and an ac power supply fed from the local area distribution capable of supporting the site operation are considered to maintain reliable operation of the HVdc scheme. The need for protection equipment for the grounding line and motor operated grounding line switches for remote configuration of line would require a dc auxiliary system.

There will be eight dc current transducers located at site. Two will measure the grounding line currents for a grounding line protection and will require continuous transmission of current measurements from the grounding site to the converter station. The requirements for grounding line protection and communication equipment is assumed based on typical arrangements, and will need to be confirmed as part of the grounding line fault detection and

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protection scheme and the grounding line design integration study. Six dc current transducers will measure the current in each group of grounding elements. The data will be logged for interrogation from the converter station upon request. Relative changes in the measured current values over time between groups of elements could detect a loss of ground elements, indicate the development of a high-resistance connection or excessive consumption of the electrode elements.

The auxiliary power supply will consist of a reliable 125-V dc supply for the monitoring and grounding line protection systems and any critical loads, and a 600-V or 208/120-V ac supply to support the dc supply and to feed heating, ventilation and other auxiliaries. The emergency back-up of the dc supply will be designed so that it can maintain supply for a duration equivalent to probable distribution supply interruptions.

Ground Potential Rise and General Impact Review

The facility shall be designed to meet the requirements stated above. The GPR distribution will be analyzed based on actual modelling during the detailed design stage.

The environmental performance and impact on the infrastructure in the vicinity of the grounding site will be assessed during the detail engineering stage. These impacts must be analyzed for the final selected site as part of further project development.

The dc currents associated with grounding site operation flow through multi-grounded distribution system neutrals, and through distribution transformers into the distribution system. The flow through a distribution transformer may result in transformer saturation and consequently failure. However it can be mitigated by replacing existing distribution transformers with transformers of higher ratings that can tolerate higher values of dc stray currents. The flow through interconnected neutrals will cause corrosion of the grounding rods. In case the consumption of grounding rods is higher than 50% (typical acceptable limit for grounding rods) over the project life cycle, these can be inspected and replaced as required. The connection of the distribution system neutrals to residential units or industrial units can be a concern, which can be mitigated by separating distribution HV and LV grounds at the pole. Typically distribution ground impedances are high in southwest Newfoundland, and the impact is expected to be limited to a small area around the grounding site.

The community buried infrastructure can be affected, and further investigation will be required based on details of the existing buried infrastructure during subsequent phases of project development. Only metallic buried infrastructure will be affected.

The telephone system is normally insulated and does allow flow of the dc stray current. A GPR difference of 70 V is acceptable and a GPR difference of less than 70 V is expected between the telephone facilities.

The potential difference across a typical bridge or structure of 100 m in length or smaller will be negligible. In case the structure is connected to remote earth via a distribution circuit or

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any other conductive connection, the dc current will not cause significant corrosion to a large structure. If the connection to the remote earth is a concern for the system connected at the other end (e.g., distribution transformers), the system can be isolated.

Estimated Quantities

At this time, quantity estimates for the development of the grounding site are based on conceptual design reviews previously undertaken for a representative site. These quantities will be updated in coming months as part of the revised conceptual design development for the currently preferred St. George's site and the subsequent detail design development for the site that is finally selected.

The site development consists of:

- Control facilities.
- Grounding line dead end structure.
- Security fencing.
- Space for truck turning movements of a WB-19 tractor-semitrailer.
- Breakwater structure; and
- Access road around the breakwater structure crest.

The characteristics of the breakwater structure are as follows:

- Depth of water at Pond Side toe of slope during Lower Low Water Large Tide to be a minimum of 2 m.
- Distance (width) from shoreline to Pond Side toe of slope to be greater than 45 m.
- Length of breakwater to be 90 m prior to returning (curve) back to shore.
- Height of breakwater assumed a 4 m wave height above Higher High Water Large Tide.
- Side slopes of 1.5 m horizontal to 1.0 m vertical.
- 6 m wide crest for access; and,
- Assumed 1.0 m of dredging.
- The breakwater structure consists of six main components: 6 m wide gravel access road, rip-rap (pond side), core stone, filter stone, armour stone (sea side); and uniform stone (allows transfer of salt water from the sea side of the breakwater to the pond side in order to maintain salinity).

Site security will be provided through a 2100-mm high chain link fence with a 300-mm Barbed Wire Overhang (BWO). Access to the site will be through manually operated swing gates.

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4.5.3 Facility Arrangements – Nova Scotia

The grounding sites associated with the Woodbine converter station selected at this time is located at Big Lorraine in Nova Scotia. The grounding site is located fairly remote from the infrastructure. The grounding design and impact assessment will be completed during the detail engineering stage.

The configuration of electrodes and the site layout will be similar to the grounding site associated with Bottom Brook in Newfoundland (NL) as described in the previous section. The bathymetry of the sea shoreline in Nova Scotia is different and layout is tailored to the area bathymetry. Similarly the auxiliaries and monitoring requirements are the same as those described for the Newfoundland grounding site facility.

Ground Potential Rise and Impact Review

See comments for Newfoundland grounding site.

Estimated Quantities

At this time, quantity estimates for the development of the grounding site are based on conceptual design reviews previously undertaken for a representative site. These quantities will be updated in coming months as part of the revised conceptual design development for the currently preferred Big Lorraine site and the subsequent detail design development for the site that is finally selected.

The site development will consist of:

- Control facilities;
- Grounding dead end structure;
- Security fencing;
- Space for truck turning movements of a WB-19 tractor-semitrailer;
- Breakwater structure; and,
- Access road around the breakwater structure crest.

The breakwater structure is located and designed to meet the following criteria:

- Depth of water at Pond Side toe of slope during Lower Low Water Large Tide to be a minimum of 2 m;
- Distance (width) from shoreline to Pond Side toe of slope to be greater than 45 m;
- Length of breakwater to be 90 m prior to returning (curve) back to shore;
- Height of breakwater assumed a 4 m wave height above Higher High Water Large Tide;
- Side slopes of 1.5 m horizontal to 1.0 m vertical;

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- 6 m wide crest for access; and,
- Assumed 1.0 m of dredging.

The breakwater structure will consist of six main components as described for the Newfoundland site. Site security arrangement will also be similar and comprise a 2100-mm high chain link fence with a 300-mm barbed wire overhang (BWO). Access to the site will be through manually operated swing gate.

4.5.4 *Contracting Strategy*

The design of the grounding sites is dependent on the design of the converter stations. The contracting strategy for implementation of these sites will either be fixed-price EPC or fixed-price supply install.

4.5.5 *Technical Feasibility*

The design of grounding sites and associated HVdc systems based on VSC technology are specialized systems offered by a few suppliers. The technical feasibility of such systems is well proven because of systems in operation and a large number in different stages of development and execution. Because of specialized design, the suppliers of these systems will be required to guarantee the performance and reliability per requirements stated above.

4.6 Grounding line

4.6.1 *Design Criteria*

The grounding line will be designed for the line voltage that will be determined as part of the ac/dc converter design. A distribution line voltage of 5 kV has been assumed for the present stage of design, and is expected to adequate based on previous experience.

The grounding line will be designed to carry two conductors (one for each dc pole) and a shield-wire. For added security against lightning strike, surge arrestors will be installed at regular intervals.

A conductor monitoring system will also be installed as part of the dc converter design.

Conductor type and size

Each of the grounding line will be equipped with two sub-conductors of ACS 954 MCM Goldenrod.

Structure types

The structures will primarily be single-pole wood structures, which are direct buried in the soil. The typical structure type is depicted in the following Figure 4.8. The structure type will be

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reviewed and qualified at the detail engineering stage considering the insulation design and dc arcs associated with the grounding line.

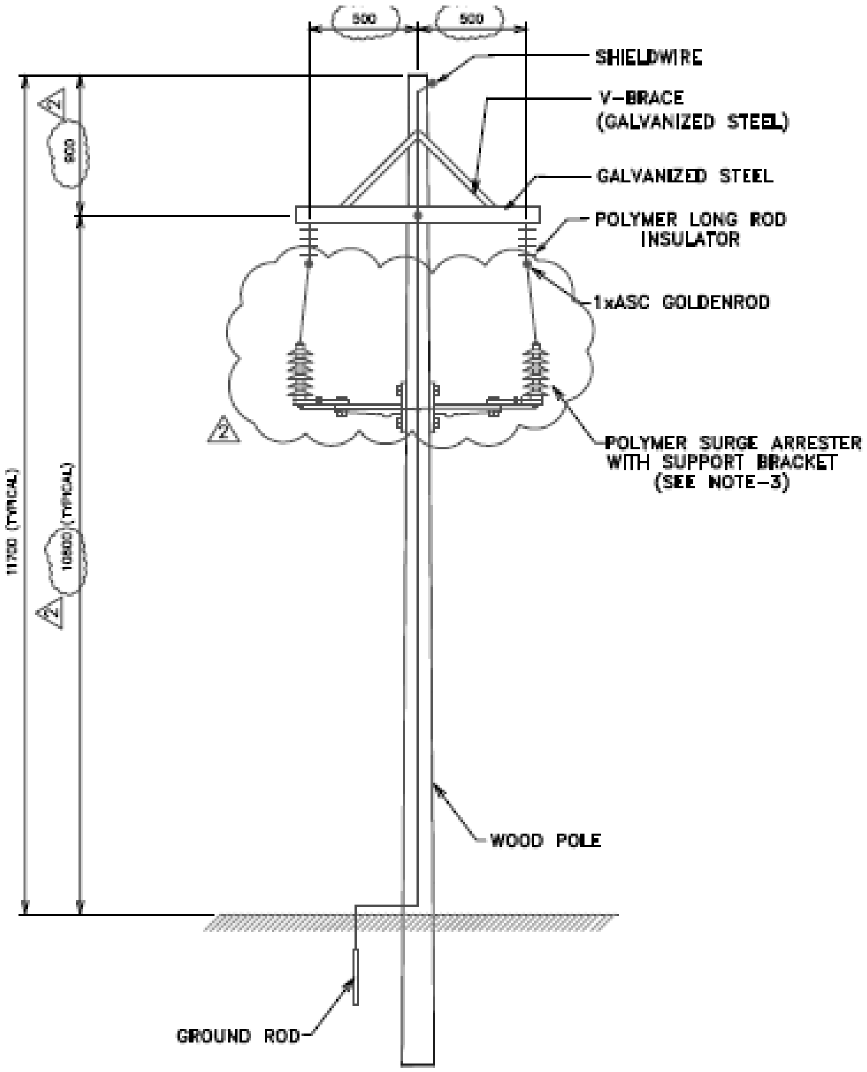

Figure 4-3: Grounding Line Structure

4.6.2 *Estimated Quantities*

The following quantities are estimated at this stage:

Grounding line in Newfoundland	28 km	433 structures
Grounding line in Nova Scotia	47 km	725 structures

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4.6.3 *Contracting Strategy*

The grounding lines will generally be installed along existing roads or transmission lines and their construction is similar to that of typical distribution lines. Therefore, the grounding lines can either be constructed as part of the HVdc transmission lines scope or through utilization of locally available distribution constructors. In either case, the preferred commercial arrangement will be as a fixed price supply-install contract.

4.6.4 *Technical Feasibility*

The design and construction of grounding lines is very similar to that of distribution lines; and hence these lines can be deemed as technically feasible.

4.7 AC System integration

4.7.1 *230-kV Transmission Line*

The 230-kV ac transmission line will be designed to the same wind and ice conditions that have been defined for the project under the HVdc transmission lines section. The insulation and structure types would be similar to those used by NALCOR for similar 230-kV transmission lines in the area, with the exception that the cross-arms and cross-braces will be galvanized steel (instead of wood) for added reliability.

The minimum vertical clearances used in design, and checked at maximum conductor operating temperature, are as follows:

Ground	8.4 m
Roads	10.6 m [maximum vehicle height = 7.6 m]
Rails	10.3 m
Navigable waterways	[Based upon Table-3 of CSA and appropriate crossing class]

Conductor Type and Size

The conductor size advised by NSPML is 795 MCM ACSR. Hatch recommends the corresponding conductor be code name ‘Drake’, which is widely used for 230-kV ac lines.

Structure Types

NALCOR has utilized wood H-framed structures on existing 230-kV transmission lines. Hatch has been provided drawings of this structure family.

The wood pole structures (but with steel cross-arm and cross-braces) are adequate for the Granite Canal transmission line.

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A typical wood pole H-framed structure is shown in Figure 4-9.

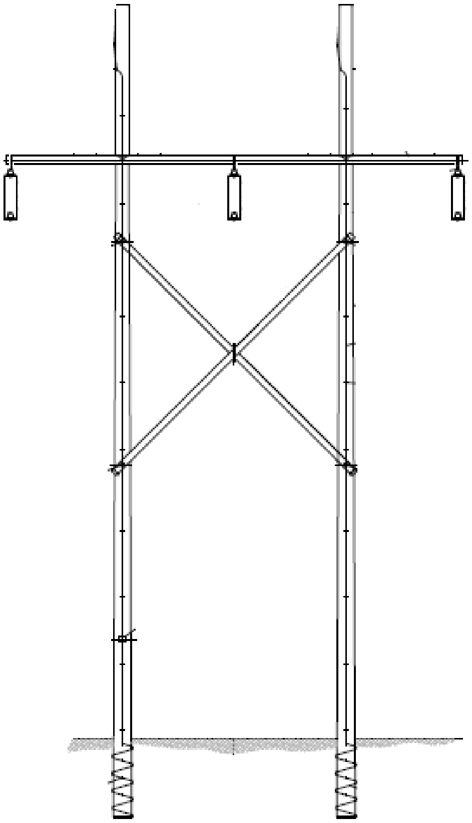

Figure 4-9: 230-kV H-framed Wood Pole Structure

Heavy-angle and dead-end structures will be 3-pole guyed wood structures.

Estimated Quantities

- Line length: 160 km
- The conductor type is single ACSR 795 Drake per phase; shield-wire type is Alumoweld steel and OPGW (Optical Ground Wire) loose-buffer tube (48-Single mode fibers) surrounded by Alumoweld steel strands. Conductor and shield-wire each include a sag and wastage allowance of 1% and 2% respectively (total 3%). The allowance for OPGW is 10% to allow for sag and wastage allowance as above and additional allowance for the increased lengths required at fiber-splicing structures.
- Total structures: 888 structures including 778 H-frames, 18 running angles, 92 dead-ends. The structure will comprise of direct buried wood poles (full-length treated Western

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Red Cedar or Douglas Fir), cross-arms (galvanized steel), cross-braces (galvanized steel) and hardware (galvanized steel).

- Geotechnical soil investigation is assumed at every 4-km length.
- Foundation and anchor quantities have been calculated based upon the following soil conditions (normal% / rock% / bog%); 25/40/35; 20/75/5 and 15/65/20 for Segments-1, 2 and 3 respectively. This translates to 20/60/20 for the overall line.
- Allowance of flood-protection has been made for 4-structures.
- Access road: Estimates prepared for lengths of new road construction and length of road upgrades.
- Tree clearing: Clearing requirements quantified for estimating purposes.
- Insulator strings: The calculated quantities for insulator assemblies are as follows; Suspension-2,328, Running angle-54, Dead-ends-564 and Jumper-282. The insulator assemblies will be single I-string for suspension and running angles. The dead-end assemblies will be double strings for security. Insulator types will be porcelain or toughened glass. Thirteen insulator-discs will be required for suspension type strings and fifteen insulator-discs for dead-end strings.
- All poles will be individually grounded. A single counterpoise connection is assumed connecting all the structures (excluding road and water crossings). The counterpoise wire will be copper-clad steel.
- Conductor accessories include suspension cushion grip clamps, compression dead-ends, full-tension splices and Stockbridge type vibration dampers. Suspension clamps for running angle structures will also include armour rods. Armour rods are not assumed as required for suspension clamps for tangent structures, but can be added if required in detailed design stage.
- Shield-wire accessories include suspension clamps, bolted or compression dead-ends, full-tension splices and Stockbridge or Spiral type vibration dampers.
- OPGW accessories include suspension clamps (AGS type including neoprene cushion and armour rods for protection), preformed dead-ends, vibration dampers, splice boxes and their attachments and down-leads (at splicing locations). The spice boxes are assumed at approximate intervals of 4-km each.
- One dead-end tower required at the Granite Canal end for termination of 230-kV line TL263 to the new Granite Canal station.
- Three double-circuit dead-end towers are required at Bottom Brook station to account for joint utilization with 230-kV line TL233.
- Modification of 138-kV line TL250 at two locations for the cross-over of the new line.

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- Modifications of 230-kV lines TL209 and TL211 for their connections to the new 230-kV station at Bottom Brook.
- Warning spheres will be added for water crossing(s) where navigation may be expected.
- Other accessories are calculated on a percentile basis.

Contracting Strategy

Same contracting strategy as for HVdc transmission lines: fixed-price (lump sum) supply-construction contract

Technical Feasibility

The design and construction of 230-kV ac transmission lines is a proven practice and multiple 230-kV ac transmission lines have been constructed by NALCOR in the project vicinity. Therefore, the 230-kV ac Granite Canal transmission line may be considered as technically feasible. As with any design, project and site specific issues will be defined and applied for the completion of an economic and effective design.

4.7.2 AC Substation Development – Granite Canal

Design Criteria

The basic design criteria for Granite Canal switching station are as defined in the following Table 4-5.

Facility Arrangements

The switchyard will be arranged in a ring bus, with four breakers. The Single Line Diagram for this switchyard is provided in Figure 4-10 below. The breaker type has been revised to allow both single-pole and three-pole operation rather than three pole operation only.

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Table 4-5: Design Criteria, Granite Canal Switchyard

Item Number	Parameters	Value
1.	Rated voltage	230 kV
2.	Rated maximumcontinuous voltage	245 kV
3	Rated Maximum temporary voltage	253 kV
4.	Rated lightning impulse level (BIL)	1050 kV
5.	Rated Frequency	60 Hz
6.	Rated bus current level	2000 A
7.	Breaker type	Outdoor, single pole, SF_6
8.	Breaker interrupting rating	31.5 kA
9.	Breaker Operation	Suitable for single pole auto-reclose, (SPAR)
10.	Breaker rated opening time	3 cycles
11.	System grounding	Effective
12.	Current transformer number	3 per bushing, per phase
13.	Current transformer ratio	1200:5 multiratio
14.	Current transformer accuracy	2.5L400
15.	Voltage transformer type	Outdoor single phase, capacitive, 2 secondaries
16	Voltage transformer accuracy	0.6WXYZ, each winding
17	Surge arrestor type	Zinc oxide varistor
18	Rated MCOV	152 kV
19	Reactor rating	15 MVAr

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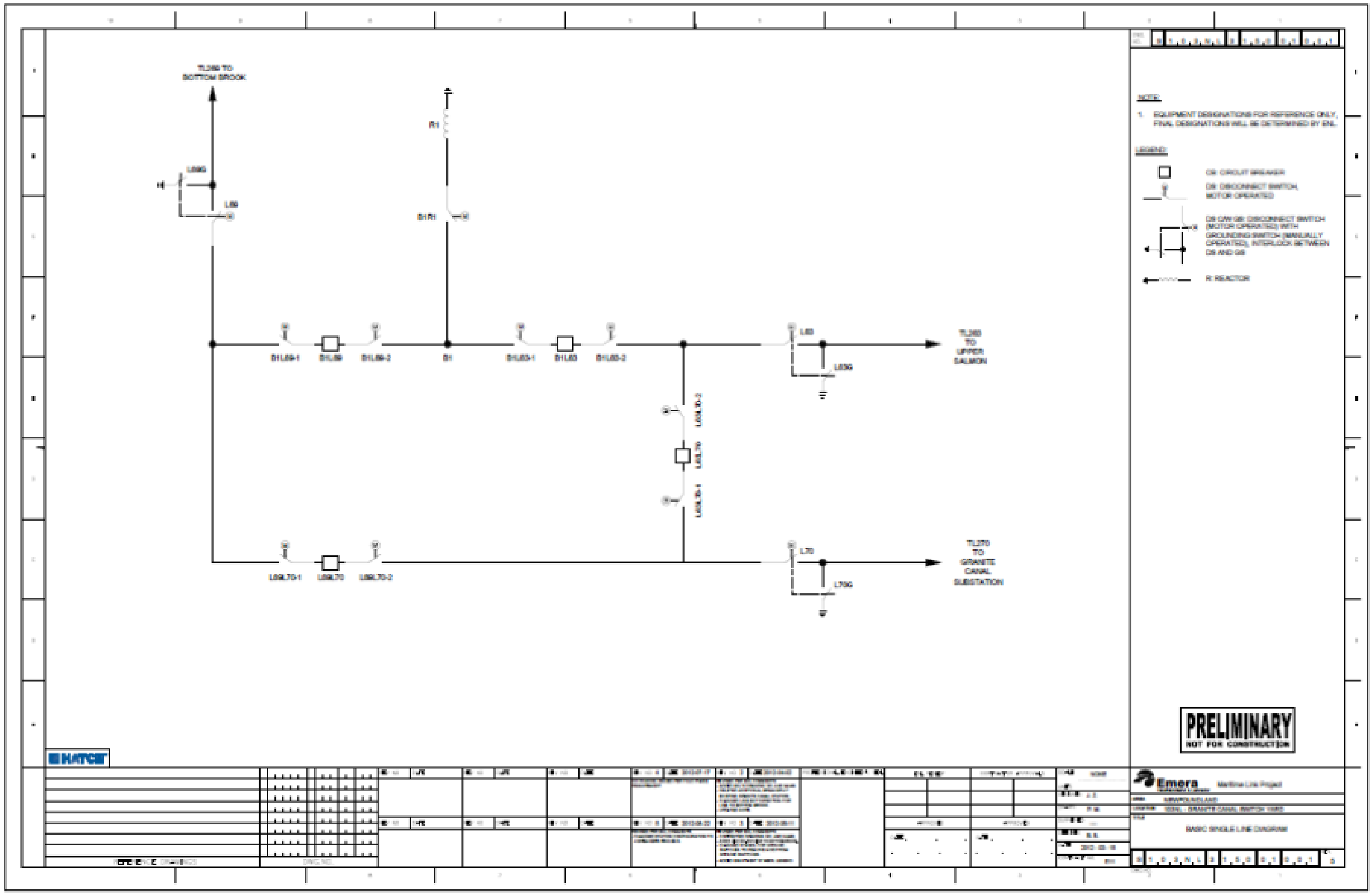

Figure 4-10: Single Line Diagram of Proposed New Granite Canal Station

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Estimated Quantities

The estimated quantity of equipment for Granite Canal Switchyard is defined in Table 4-6 below.

Table 4-6: Electrical Equipment Quantities, Granite Canal Switchyard

Item No.	Item Name	Quantity
1.	230-kV circuit breakers	4
2.	230-kV capacitive voltage transformers	12
3	230-kV surge arrestors	12
4.	230-kV disconnect switches	9
5	230-kV line disconnect switches, with grounding switch	4
6	230-kV reactor	1

Contracting Strategy

It is planned to complete detailed design and then contract for turnkey supply-construct, with some long-lead items procured by the owner.

Technical Feasibility

It is completely feasible to build the Granite Canal switching station in the location proposed.

4.7.3 AC Substation Development – Bottom Brook

Design Criteria

The basic design criteria for the Bottom Brook switching station are as defined in the following Table 4-7.

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Table 4-7: Design Criteria, Bottom Brook Switchyard

Item Number	Parameters	Value
1.	Rated voltage	230 kV
2.	Rated maximum continuous voltage	245 kV
3	Rated maximum voltage 30 min	253 kV
4.	Rated lightning impulse level (BIL)	1050 kV
5.	Rated Frequency	60 Hz
6.	Rated bus current level	2000 A
7.	Breaker type	Outdoor, single pole, SF_6
8	Breaker operation	Suitable for single pole auto-reclose, (SPAR)
9.	Breaker interrupting rating	40 kA
10.	Breaker rated opening time	3 cycles
11.	System grounding	Effective
12.	Current transformer number	3 per bushing, per phase
13.	Current transformer ratio	2000:5 multiratio
14.	Current transformer accuracy	2.5L800
15.	Voltage transformer type	Outdoor single phase, capacitive, 2 secondaries
16	Voltage transformer accuracy	0.6WXYZ, each winding
17	Surge arrestor type	Zinc oxide varistor
18	Rated MCOV	152 kV
19	Combined revenue metering instrument transformer, accuracy	Voltage 0.3WXYZ Current 0.3, ratio 1200:5

Facility Arrangements

The switchyard will be arranged in a compact one and one half breaker arrangement, with 4 diameters of 3 circuit breakers each. The Single Line Diagram for this switchyard is provided in Figure 4.11 below.

The breaker type has been revised to operate both single pole and three, versus the previous expected operation as three pole only.

Estimated Quantities

The estimated quantity of equipment for Bottom Brook switchyard is defined in the table below:

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Table 4-8: Electrical Equipment Quantities, Bottom Brook Switchyard

Item No.	Item Name	Quantity
1.	230-kV circuit breakers	12
2.	230-kV capacitive voltage transformers	30
3.	230-kV coupling capacitors	4
4	230-kV surge arrestors	18
5.	230-kV bus disconnect switches	24
6	230-kV line disconnect switches, with grounding switch	6
7	230-kV combined instrument transformers	6

Contracting Strategy

It is planned to complete detailed design and then contract for turnkey supply-construct, with some long-lead items procured by the Owner.

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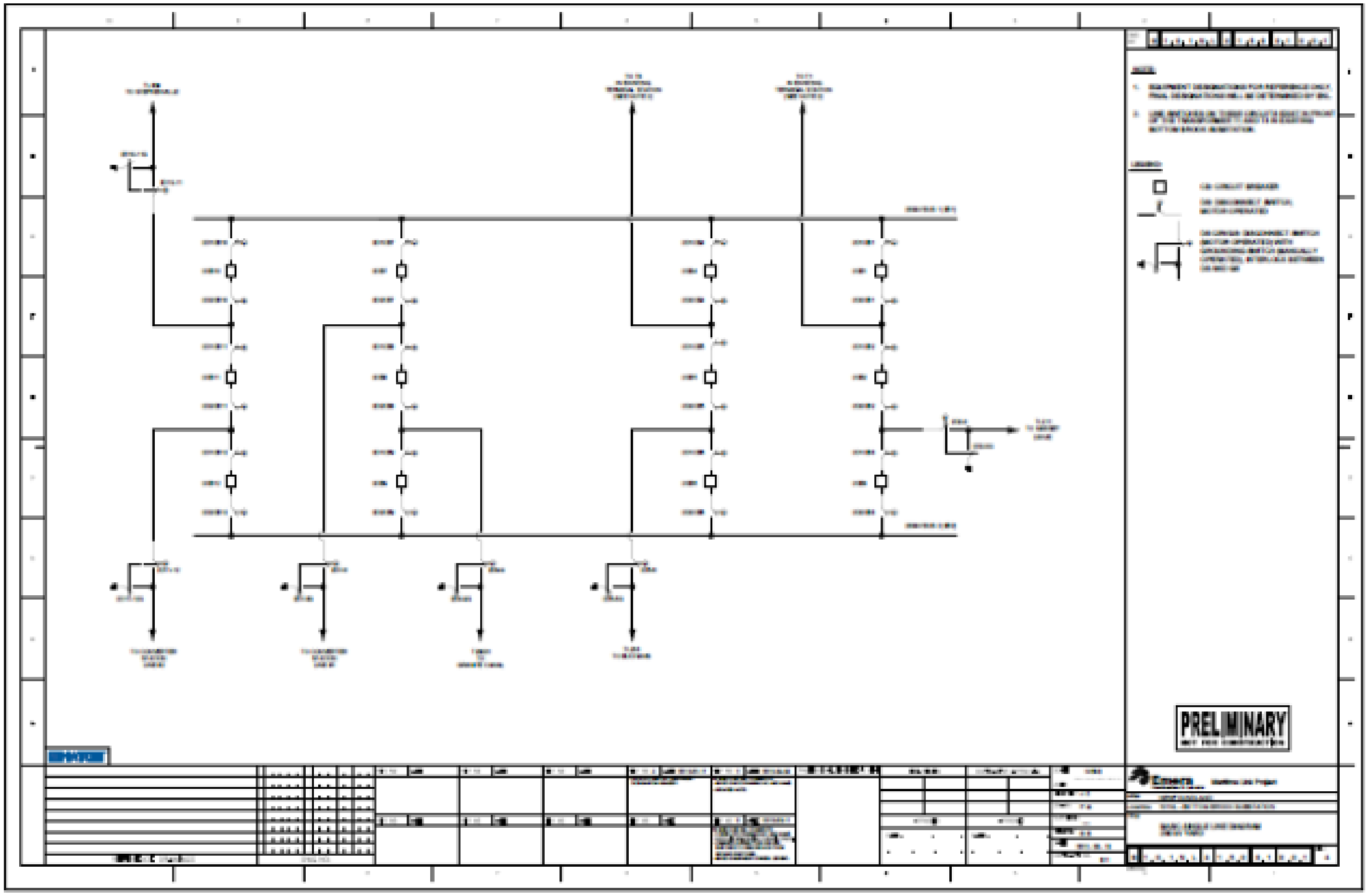

Figure 4-11: Single Line Diagram of Proposed New Granite Canal Station

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Technical Feasibility

The design concept for the Bottom Brook 230-kV switchyard presents no technical challenges regarding the technologies and design techniques being deployed. The station has been designed in accordance with industry standard configurations which are in common use in NLH and NSPI.

While it is technically feasible to construct the proposed new Bottom Brook 230-kV switchyard at the proposed site adjacent to the existing substation, the transfer of existing circuits TL 209, TL 211 and TL233 from the existing substation to the new switchyard constitutes some staging challenges. At times during the sequence of transfer and reconnection of existing circuits to the new switchyard, the reconnection of the two 230-kV circuits to the 230/138-kV autotransformers, and the extension of the existing station service facilities connected to the autotransformer tertiaries, live-line practices may have to be used and lines TL 214 and TL250 as well as line TL 209 may have restricted supply capacity. During this period, it may be necessary to use the aged gas turbine facility connected to line 209 near Stephenville to supply Stephenville and other parts of south west Newfoundland. This situation will require very careful planning to ensure the most reliable staging of supply transfer and service to customers in the south western portion of Newfoundland.

4.7.4 AC Substation Development – Woodbine

Design Criteria

Design development for the expansion of Woodbine Substation will be undertaken by Nova Scotia Power Inc, in accordance with design criteria in use by NSPI.

Facility Arrangements

The 345-kV portion of the Woodbine substation will be expanded to accommodate connections for two converter transformers. Details of facility arrangements are being developed by Nova Scotia Power Inc.

Estimated Quantities

The estimated quantities of major materials are being estimated by Nova Scotia Power Inc, based on design development carried out by NSPI.

Contracting Strategy

The contracting strategy for Woodbine Substation is being driven by Nova Scotia Power Inc.

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Technical Feasibility

The construction of the proposed 345-kV expansion of the Woodbine substation appears to be entirely feasible. Nova Scotia Power Inc has managed a substantial 345-kV network for many years, and has developed and expanded 345-kV switchyards and substations throughout Nova Scotia. No significant problems are foreseen for Nova Scotia Power Inc to expand the existing Woodbine Substation to accommodate the additional connections.

5. Operation of the Maritime Link

5.1 Operating Modes

The Maritime Link will have two principal operating modes: a “normal” mode, with both poles in operation, and a “single contingency” mode with either of the two poles out of service.

5.2 Normal Operation

The Normal mode of operation corresponds to both poles in service. Each pole is rated for operation at a 200 kV potential difference compared to ground, and each pole is capable of delivering 1250 Amperes or 250 MW. With both poles in service, the system will deliver 1250 Amperes on one pole, which will return on the other pole, and the total power delivery will add to 500 MW. No current will return through the earth path as long as the current sent and received is exactly equal, but if any minor difference exists between the current sent and received, the difference will return through the earth path.

5.3 System Response to Equipment Failures

In the uncommon event of an interruption to either the positive or negative pole, the dc system will be reduced to a single 200-kV monopole supplied by the healthy pole, and 1250 Amperes will be delivered into the healthy pole conductor and will return through the earth.

Such interruptions may occur as a result of manual switching operations, for planned maintenance. These interruptions may also occur as a result of various failures on the overhead HVdc lines or the underground or submarine cables, or within the ac/dc converter equipment at either end of the HVdc link. The ac/dc converters have built-in controls to rapidly shut down either pole in the event of such failures. Shutdown of a single pole, either by manual action or by automated control, will not affect the ongoing operation of the other pole.

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5.4 Operation After Equipment Failures

In the immediate aftermath of a pole shut-down, either from manual intervention or from automated response to a system failure, the power being delivered into that pole will immediately drop to zero, but there will be no impact on the power delivered to the other pole. One 200-kV pole will be isolated, and the other 200-kV pole will continue to carry 1250 Amperes of current, using the earth path as the return path for the current being carried in the healthy pole conductor.

5.5 Repair and Restoration After Equipment Failure

The system is designed to continuously carry 1250 Amperes after a pole is removed from service, either due to manual intervention or due to automated isolation in response to a system failure. The system capacity will effectively be reduced to 250 MW until such time as the isolated pole is returned to service.

Longer term repair and restoration after equipment failure is an important and urgent requirement, but most situations leading to pole isolation will require some time for restoration or repair.

For failures within the ac/dc converters, maintenance forces must be dispatched to the site of the failed converter, and repairs are likely to require replacement of failed modules within the rectifier/inverter banks. Total elapsed time for dispatch of maintenance crews, trouble-shooting and component replacement is likely to be measured in hours or days.

For failures in the aerial HVdc transmission lines, maintenance forces must be dispatched to the segment of the line that has failed, and line patrols must be undertaken to locate the source of the failure, followed by repair/replacement of the equipment that has failed. Again, the total elapsed time is likely to be measured in hours or days.

For failures in the submarine cables, specialized cable repair ships must be summoned and dispatched to the area where the failure has been localized. Spare cable and splices will be available in storage with NSPML, as part of the supply contract for the submarine cable system, and these spares will be delivered to the repair ship when it arrives at site. The repair ship will raise the damaged cable from the ocean floor, splice in healthy cable to replace the failed cable section, and return the cable to the ocean floor at the end of the repair process. These cable repair ships are not readily available, and total elapsed time from cable failure to cable repair and restoration is likely to be measured in months.

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