Q. What is the expected annual energy availability, scheduled energy unavailability and forced energy unavailability of (a) the Labrador-Island Link and (b) the Maritime Link? Please provide the availability studies that document the failure rate, mean time to repair, required maintenance, required spare parts, redundancy of in-service equipment, response time of qualified HVDC O&M personnel to report to the site when called-out to investigate faults, number of HVDC O&M personnel required and required skill sets of O&M personnel.

A. The availability study for the Labrador-Island Link is provided in "Reliability & Availability Assessment of the HVdc Island Link" (Nalcor Document Number ILK-SN-CD-8000-EL-SY-0004-01) provided as PUB-NLH-212 Attachment 2.

The converter specification for the Labrador-Island Link requires that the total number of pole forced outages shall be less than five per pole per year and that the total number of bipole forced outages shall be less than one per ten years.

The Labrador-Island Link converter manufacturer is required to provide availability and forced outage calculations on the assumption of a four-hour response time for O&M personnel.

Availability values for the Maritime Link converters are specified as follows:

Annual energy availability – Greater than 98%
Scheduled energy unavailability – Less than 1.5 %
Forced energy unavailability – Less than 1%

The total number of pole forced outages shall be less than four per pole per year and the total number of bipole forced outages shall be less than one per ten years.

Availability considerations for the Maritime Link are addressed in Nova Scotia Power's responses in support of the application of the Maritime Link Project before the Nova Scotia Utility and Review Board. The responses to Request IR-194 and Request IR-371 from the Consumer Advocate/Small Business Advocate address reference materials relating to the reliability and availability of Voltage Source Converter (VSC) HVdc systems. A copy of IR-194 is provided as CA-NLH-050 Attachment 1. A copy of IR-371 is provided as CA-NLH-050 Attachment 2.

Discussions relating to repair times for the Maritime Link are included in the responses to Request IR-5, IR-21, and Request IR-35 from Cable Consulting International Ltd. Copies of IR-5, IR-21 and IR-35 are provided as CA-NLH-050 Attachments 3 to 5 respectively.

Emera NL will be working with the Maritime Link vendor during the design process to assess response times.

For both HVdc links the number of O&M personnel and their required skill sets necessary to respond to investigate faults within the system will depend upon the type of fault. Given the nature of the HVdc systems and equipment located within the converter stations, qualified personnel will include:

- Protection and control technologists;
- Communication technologists;
- Electricians;

- Mechanical technologists;
- Millwrights; and
- Line workers.

The vendors of the converter equipment will be required to ensure during the design, installation and commissioning phases of the projects knowledge transfer and training of required O&M staff in the vendor specific technologies and required maintenance practices.

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Request IR-194:

With reference to Appendix 3.01, page 76, please provide any reports, studies, reviews, or other materials with the analyses of the industry statistics related to the based on VSC technology HVDC converter valve groups and their cooling systems, including aging evaluation, forced outage rates, reliability in service, failure modes, etc. To the extent a report is subject to the strict copyright laws (e.g., a CIGRE report) please provide a summary of the report observations and conclusions.

Response IR-194:

There are limited statistics collected for the VSC based HVdc systems yet, although there is a protocol established for data collection. Many of the components of the VSC HVdc systems are similar to the LCC HVdc systems with the exception of valves and phase reactors, therefore the available statistics for LCC HVdc as it relates to components (for example, converter transformers) can be helpful. CIGRE has collected the reliability statistics for a large number of HVdc links with reports available to the CIGRE members.

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Request IR-371:

With reference to CA/SBA IR-194 and Appendix 3.01, page 76, please provide any reports, studies, reviews, or other materials with the analyses of the industry statistics related to the based on VSC technology HVDC converter valve groups and their cooling systems, including aging evaluation, forced outage rates, reliability in service, failure modes, etc. To the extent a report is subject to the strict copyright laws (e.g., a CIGRE report) please provide a summary of the report observations and conclusions.

Response IR-371:

As indicated in the response to CA/SBA IR-194, protocols have been developed for data collection on VSC installations, but the industry has not yet started compiling the statistics. The following is summary data from CIGRE for LCC installations for the operating period 2009-2010, showing the relative contributions of various components in an HVdc system to the overall Forced Energy Unavailability of the system. The components referenced in the figure are:

- AC-E AC and Auxiliary Equipment
- V Valves
- C&P Control and Protection
- DC-E DC Equipment
- O Other
- TL Transmission Line or Cable

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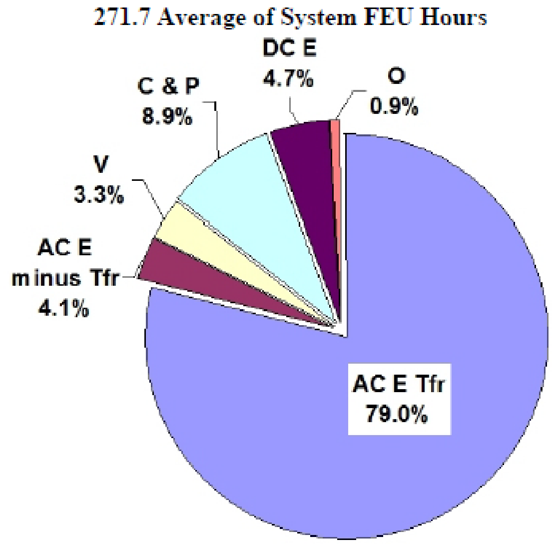

Figure 1
Breakdown of Average FEU By Equipment Category of All Reporting Thyristor HVDC Systems (2009-2010)

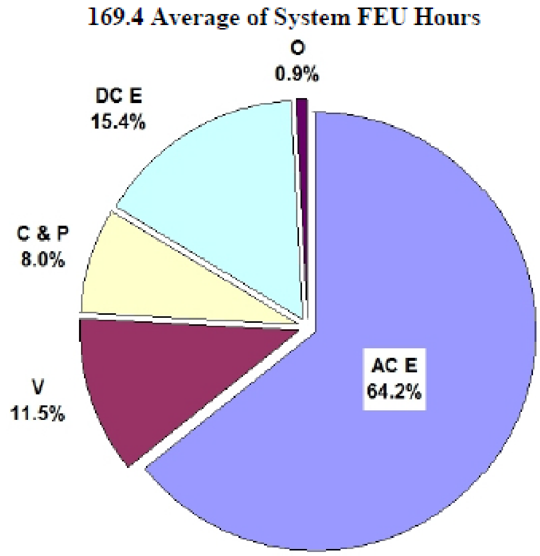

Figure 2
Breakdown of Average FEU By Equipment Category of All Reporting Thyristor HVDC Systems (1983-2008)

Source: CIGRE B4_113_2012: “A Survey of the Reliability of HVDC Systems Throughout the World During 2009-2010”

These statistics demonstrate that in both periods (1983-2008 and 2009-2010); AC Equipment and Auxiliaries (AC-E) are the dominant contributors to Forced Energy Unavailability. Within the category of AC Equipment and Auxiliaries, transformers have been a significant contributor. The contributions for Valves (V) cannot be validated for VSC installations, but a significant reduction of FEU contributions from LCC thyristor valves has been observed in recent years.

As noted, performance reporting for VSC systems is in its infancy, and reporting to date has been ad hoc and does not conform to standardized reporting templates. A 2010 CIGRE report dealt with the performance of two VSC systems that have been in service for 10 years or more: the Cross-Sound Cable project in the USA and the Murraylink Project in Australia.

The Cross-Sound Cable project is a +/-150-kV 330 MW symmetrical monopolar HVdc project linking Connecticut to Long Island New York through submarine XLPE cables. The project was

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commissioned in August 2002, and performance of the system has been recorded since that time. The manufacturer's design targets included a Forced Outage Rate of 1.18 percent (103.6 hrs per year) and a Scheduled Outage Rate of 0.82 percent (72 hrs per year), with a total Energy Availability of 98 percent. Performance reported from 2003 to 2009 has been as shown in the table below:

Year	Forced Outage (%)	Scheduled Outage (%)	Energy Availability (%)
	Target is 1.18%	Target is 0.82%	Target is 98%
2003	0.74	0.69	98.57
2004	2.73	0.67	96.60
2005	0.93	0.96	98.11
2006	0.12	1.17	98.71
2007	0.81	4.03	95.16
2008	0.93	3.60	95.47
2009	1.87	2.34	95.79

Source: CIGRE B4_203_2010: "HVDC VSC (HVDC light) transmission – operating experiences"

The Forced Outage Rates have largely met expectations, whereas specific events between 2006 and 2009 have led to Scheduled Outage Rates falling above target and Energy Availability falling below target. Most of these events were related to AC equipment and auxiliaries, as opposed to the IGBT valves. The IGBT valves have generally performed better than the targeted performance. With a total of 2916 IGBTs at each converter (5832 in total), the targeted failure rate was 29.2 failures per year (0.5 percent), and the performance by year has steadily improved from 34 failures in 2003/04 to 7 failures in 2009/10.

The Murray Link Project is a +/- 150-kV 220-MW project connecting South Australia to Victoria State by 180 km of underground XLPE cables. The project was commissioned in 2002. The principal performance measure that has been tracked on the project since commissioning is the energy availability, targeted at 98 percent. Results have been as follows:

Energy Availability	2003	2004	2005	2006	2007	2008	2009
Total	95.18%	97.08%	95.39%	98.92%	90.56%	99.17%	99.37%
Scheduled	96.49%	98.77%	97.96%	98.51%	97.91%	99.12%	99.13%
Forced	98.21%	98.04%	97.11%	99.33%	90.98%	99.86%	100.00%

Source: CIGRE B4_203_2010: "HVDC VSC (HVDC light) transmission – operating experiences"

The only significant performance shortfall occurred in year 2007, and was attributable to a failure in the AC Equipment and Auxiliaries category.

As older vintage VSC installations, the Cross Sound and Murray Link converters are not directly comparable to the VSC technology that will be implemented on the Maritime Link Project. However, the specifications now under development for the Maritime Link converters call for Forced Energy Unavailability less than 1.0 percent and Scheduled Energy Unavailability less than 1.5 percent, and total Energy Availability of 98 percent, similar to the targets set on other projects over the past decade. Similarly, the IGBT failure target is 0.5 percent per year, similar to the targets set on other projects over the past decade.

The largest contributions to annual energy unavailability, both for LCC facilities and VSC facilities as summarized above, come from AC equipment and auxiliaries, and transformers in particular. The accumulated industry experience related to AC Equipment and Auxiliaries, in both LCC and VSC facilities, is applicable to the Maritime Link Project, and the lessons learned in recent applications will be factored into the design development and spares strategies for the Maritime Link converters. The specifications for the converter stations include prescribed spares requirements for a list of 26 separate components, including converter transformers and IGBT valves, and the proponents for the converter contract are required to identify supplementary spares requirements as needed to meet the reliability criteria.

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Request IR-5:

With respect to page 47, line 7 of the Application which states that "During monopolar operation, full load current of 1, 250 A may flow through the return path, it must maintain that power level even during planned or unplanned outages on either of the poles", please advise:

(a) What maintenance periods NSPML envisage for planned outages?

(b) What repair times NSPML envisage for unplanned outages?

(c) What length of time NSPML envisage for changing between bipolar and monopolar operation?

(d) What is the envisaged availability of the Maritime link as a bipolar system?

(e) What is the envisaged availability of the Maritime link as a monopolar system?

(f) How have the availabilities been calculated?

Response IR-5:

The power level which will be required during mono-pole operation will be dependent on the actual MW transfer at any given time. Higher current is required for higher transfer levels and current decreases as transfer levels reduce. The 1250 amp is required when transfer levels are maintained at 250 MW on one pole.

Please refer to MPA IR-8 and MPA IR-5.

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(a) Planned maintenance will be based upon supplier recommendations and Good Utility Practice. The outages will include an anticipated bi-annual (2 year cycle) for converter maintenance, routine maintenance will be completed without outage requirements. The converter stations are designed to achieve operational reliability levels consistent with this maintenance cycle and will be validated during the procurement process. Predictive and preventative maintenance which can be completed in a planned or scheduled manner will be an operating objective, such as monitoring equipment operating temperatures to time repairs or intervention with scheduled outages. The outage duration for planned maintenance, outside overhauls, will be the equivalent of approximately 3-5 days per year. During planned maintenance, it is likely that the second cable would be available to be used as the return path, reducing the operating time of the grounding system. Overhauls could be every 2-3 years.

(b) VSC converter technology has a high reliability, with design considerations included to achieve uninterrupted operation between bi-annual planned maintenance periods. Unplanned outages on traditional overhead infrastructure is minimal for transmission systems of this design and both utilities have extensive experience operating and maintaining lines in the same territory. The duration of unplanned outages for subsea cables can vary depending upon the location and timing of the failure. Outages in the deep water areas require more specialized equipment to be available to carry out the repair, while in more shallow waters a greater number of vessels could be considered. The timing of the failure can lead to delays based on either the availability of suitable vessels and/or weather conditions which would allow the repairs to be carried out safely. The repair times could be in the range of 2-8 months depending upon the location and the time of year.

(c) NSPML has not finalized design of the switching, however, the length of time expected could range from less than one hour to several hours depending on final design criteria to change between bipolar and monopolar operation.

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(d–f) The availability target for the Maritime Link is presently 95-97 percent and will be validated during final design and review of supplier performance characteristics. The Maritime Link will be planned to operate in bipolar mode at all times. The operating criteria will be finalized during the converter design with an expectation of bi-polar mode on a continuous basis and capability to operate in mono-polar similarly if required. The availability is based upon experienced reliability levels of typical overhead high voltage transmission systems, converter availability, no projected major cable failures and includes all routine substation and converter maintenance which requires unavailability of the plant being performed during bi-annual planned shutdowns for all components in the pole.

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Request IR-21:

With respect to page 61 line 24 of the Application which states that "An important aspect of submarine cable systems is their exposure to damage from marine vessels, ship anchors, and pack ice, with long delays for repair or replacement of damaged cables", please supply details of the repair strategies, including holding of spares, availability of vessels and personnel, that have been, or are to be, developed to ensure that the HVDC submarine cable system can be returned to service in the event of either third party activities or intrinsic failure?

Response IR-21:

NSPML will develop a cable inspection and a cable repair program as part of the Long Term Asset management program (LTAMP), which will include retention of spare parts, inspection frequencies for the cable, monitoring and remediation programs based upon the final design and installation program results. The repair program will include spare part requirements, storage requirements, safety and environmental standards, root cause investigation and repair procedures, resource requirements including vessel size and availability and will consider retention of services with suppliers or experienced repair companies. NSPML is aware of proponents on the east coast who maintain a repair barge for shallower depths and will investigate other options prior to the installation campaign.

Spares requested as part of the request for proposals include:

- 5000 m of subsea cable on a turn table

- Subsea jointing kits.

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Request IR-35:

With respect to the expected availability of the Maritime Link, in particular,

(a) the response to IR-5, to which NSPML have responded in (b) that the repair times for subsea cables could be in the range of 2-8 months and in (d-f) that the availability target is presently 95-97 percent and that their forecasts do not include any projected major cable failures and with respect

(b) to the responses given to file M-5 (Morrison Park Advisors), IR-5, and M-5, IR-8.

Please supply the calculation of availability of the Maritime Link that NSPML has performed, including:

(a) What maintenance periods for planned outages have NSPML used in their calculation?

(b) What repair times for unplanned outages have NSPML used in their calculation?

(c) What failure rates NSPML have used in their calculation

(d) What length of time for changing between bipolar and monopolar operation have NSPML used in their calculation?

(e) The sources of the above data?

(f) What is the calculated availability of the Maritime Link as a bipolar system?

(g) What is the calculated availability of the Maritime Link as a monopolar system?

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(h) How do calculations indicate that these would change over the 50 year life of the cable?

Response IR-35:

(a-h) The expected availability of the Maritime Link is based on specified design requirements and historical performance data.

The design of the VSC converter incorporates redundant IGBT valves such that the system can continue to perform at full load while experiencing some valve failures. The level of redundancy built into the design, in conjunction with predicted valve failure rates, allows the supplier to design the converters to high reliability levels. NSPML has specified that the converter be designed with sufficient redundancy to guarantee a Forced Energy Unavailability Rate of less than 1.0 percent, a Scheduled Energy Unavailability rate of less than 1.5 percent and a total Energy Availability rate greater than 98 percent. NSPML has also specified that the total number of 'pole' force outages shall be less than 4 per year and that the total number of 'bi-pole' forced outages shall be less than 1 per 10 years. The converter suppliers will be required to design their systems with sufficient built in redundancy to guarantee these values are met.

NSPML has presumed switching from bi-pole to mono-pole to be within the unavailability percentages as the transfer will be automated and instantaneous. Switching to place the second cable into return path mode will be through the use of motorized switching and would be complete within hours but does not disrupt mono-pole operation either during this period.

All scheduled maintenance activities on the cable and overhead HVdc lines will be planned to coincide with converter maintenance periods. Scheduled maintenance is included within the 1.5 percent Scheduled Energy Unavailability requirement noted. The converter will be designed such that maintenance can be performed on one pole while the

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other is still in service. During scheduled maintenance periods the converter will operate in monopole mode switched to metallic return.

Sustained forced outages on overhead transmission lines are infrequent and design life will be a 50 year return period with no major failures. Fault locating monitors will be installed in the system protection to ensure that any potential faults can be located and responded to quickly.

The design of the cable and installation campaign will contain specific measures aimed at reducing the likelihood of a failure resulting from design, manufacturing, handling, installation, protection or operation of the cables. The purpose of the attention to each of these stages is to reduce the likelihood of any failure mechanism through the entire life of the cable, however accidents occur and plans to repair the cable will be based upon local conditions, industry standards and manufacturers recommendations. Cable faults are also rare. NSPML will have spare cable and jointing materials in spare parts inventory to minimize downtime in such a circumstance. In the event of a single cable failure the system will be capable of operating in a monopole mode with sea return. Since NSPML is planning to ensure the cable is protected from risks and warranty periods will cover manufacturer's installation risks, we have not modeled any failure of cables requiring recovery of the cable from the seabed through the life of the cable.

NSPML will retain emergency repair procedures as part of a risk management plan, similar to environmental and safety management, which is aimed at being prepared in the unlikely event of a failure.

For assessment of the implications of a failure, numerically the 2-8 month repair time for a cable failure is based upon a suitable vessel availability and a weather window that will allow minimal delays to complete the work economically. The vessel must be secured and fitted with sufficient equipment to recover the cable from the depth where the failure is located, travel to the Cabot Strait, complete the repair and reposition the cable.

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Recovery time would be approximately one month to equip the vessel and travel to site, and actual repair time would be approximately one week (the minimum two months would include variance in the vessel preparation and repair times). The longer period of up to 8 months would be based upon tight vessel availability or a failure occurring late in the fall with an early winter setting in, preventing repair from occurring until the spring when ice pack has cleared sufficiently. For illustrative purposes only, a 2 month cable outage, even if it occurred once in ten years, would reduce the 10 year average availability from 98 percent to 97.4 percent, and one 8 month repair in 50 years would reduce the average availability from 98 percent to 96.3 percent. In both cases, the lower availability is the result of the mathematical reduction of 2/12th and 8/12th of one cable for one year in each respective scenario.

The combined availability of the converters at 98 percent and a system designed and constructed to achieve a 50 year life without failure should comfortably deliver reliability in excess of the 95-97 percent conceptual design estimate without deterioration.

Please refer to SBA IR-371 for historical performance data of HVdc Systems.