Q. Please provide the expected service outage events per year for the system consisting of Muskrat Falls, the dc line from Labrador and the ac output of the inverter at Soldiers Pond.

A. Please refer to Hydro's response to PUB-NLH-217 for a detailed description of the impacts on the Island Interconnected System reliability for the monopolar and bipolar loss of the Labrador – Island HVdc Link.

Attachment 2 included in response to PUB-NLH-212, "Reliability & Availability Assessment of the HVdc Island Link" dated April 10, 2012 completed by SNC- Lavalin provides a detailed assessment of the impacts of the HVdc link on the Island Interconnected System. Table 3-2 of this report provides the composite Labrador – Island HVdc Link bipole reliability. The total failure rate for the bipole was calculated to equal 0.7078 failures per year as summarized below. However, incorporating the manufacturer's performance guarantees for the proposed HVdc converter equipment at Muskrat Falls and Soldier's Pond it is anticipated that the failure rate will reduce to no more than 0.3278 per year as described below.

The most significant contributors to the bipole failure rate are the common-mode failure of both poles due to converter faults (BP) calculated at 0.24 failures per year per converter station and the main overhead line bipole faults calculated at 0.074 failures per year for BPL1 (the 388 km section in Labrador) and 0.13 failures per year for BPL2 (the 680 km section on the Island).

Summary of PUB-NLH-212 Attachment 2 Table 3-2	
Element	**Failure Rate (f/yr)**
BP – Muskrat Falls	0.24
CP+CP – Muskrat Falls	0.0084
BPL1 – 388 km	0.074
P1 + P2 (cables)	0.007
BPL2 – 680 km	0.13
CP + CP – Soldiers Pond	0.0084
BP - Soldiers Pond	0.24
Total	0.7078

The analysis conducted in Attachment 2 references CIGRE historical data. The bipole converter failure rate of 0.24 failures per year is the average of the 2007 and 2008 bipole failure rates for the reporting systems consisting of two HVdc terminals with one converter per pole as per the Labrador – Island HVdc Link design. The average of the two years provides a slightly more conservative failure rate than the bipole failure rate of 0.21 failures per year for the period 1988 – 2008 as shown in Appendix B of the Attachment 2 report. A review of the historical data provided in Attachment 2 Appendix B highlights that the HVdc systems contributing to the bipole failure rate are limited to four HVdc systems that, as of 2008, had been in service between 18 and 20 years. A total of seven HVdc systems ranging in age from five to 19 years had experienced no bipole failures of the converters during the reporting period.

The Labrador – Island HVdc Link converter specification includes a maximum permissible design value bipole forced outage rate of ≤ 0.1 per bipole per year, or no more than one bipole outage in ten years for both converters. Given this performance requirement, the summary table above is adjusted for the BP failure rates (i.e., 0.05 per converter).

Modification to PUB-NLH-212 Attachment 2 Table 3-2 For Labrador - Island HVdc Link Converter Bipole Failure Rates	
Element	**Failure Rate (f/yr)**
BP – Muskrat Falls	0.05
CP+CP – Muskrat Falls	0.0084
BPL1 – 388 km	0.074
P1 + P2 (cables)	0.007
BPL2 – 680 km	0.13
CP + CP – Soldiers Pond	0.0084
BP - Soldiers Pond	0.05
Total	0.3278

The adjusted total provides a total bipole failure rate of 0.3278 per year, or one bipole failure every three years.

Tables 3A and 3B provide the number of forced outages and equivalent outage hours for two terminal HVdc systems containing one converter per pole for the years 2007 and 2008 respectively from the CIGRE data.

Table 3A - Number of Forced Outages and Equivalent Outage Hours - 2007

System	**AC-E**		**V**		**C & P**		**DC-E**		**O**		**TL**		**Total**	
	#	**Hours**	**#**	**Hours**	**#**	**Hours**	**#**	**Hours**	**#**	**Hours**	**#**	**Hours**	**#**	**Hours**
Skagerrak 1 & 2	1	0.2	0	0.0	2	6.0	0	0.0	2	1.5	0	0.0	5	7.7
Square Butte	1	4.4	0	0.0	2	0.3	1	3.6	3	0.8	2	194.6	9	203.7
CU	1	0.3	0	0.0	0	0.0	1	23.5	0	0.0	1	0.1	3	23.9
Gotland 2 & 3	0	0.0	1	0.4	0	0.0	0	0.0	0	0.0	0	0.0	1	0.4
Fennoskan[1]	2	43.7	0	0.0	3	29.0	1	2.0	0	0.0	1	1005.5		1080.1
SACOI[2]	7	13.5	0	0.0	2	2.4	0	0.0	1	1.5	3	530.3	13	547.7
New Zealand 2	3	14.9	0	0.0	2	6.8	0	0.0	0	0.0	1	0.3	6	21.9
Kontek[1]	0	0.0	0	0.0	1	2.8	0	0.0	0	0.0	1	1624.5	2	1627.3
SwePol	0	0.0	0	0.0	0	0.0	0	0.0	1	2.4	0	0.0	1	2.4

Kii Channel	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Grita[1,2]	3	5.8	2	13.2	2	5.2	1	313.7	0	0.0	1	610.5	9	948.4

Notes
AC-E: AC and Auxiliary Equipment; V: valves; C&P: Control and Protection; DC-E: DC Equipment; O: Other;
TL: Transmission Line or Cable
1 Major time cause by cable failures
2 Major time caused by smoothing reactor

Table 3B - Number of Forced Outages and Equivalent Outage Hours - 2008

System	AC-E		V		C & P		DC-E		O		TL		Total	
	#	Hours	#	Hours	#	Hours	#	Hours	#	Hours	#	Hours	#	Hours
Skagerrak 1 & 2	2	0.3	0	0.0	6	15.8	0	0.0	1	0.1	0	0.0	9	16.2
Square Butte	1	6.6	0	0.0	15	0.7	0	0.0	5	0.8	1	64.5	22	72.6
CU	4	145.6	0	0.0	1	0.7	0	0.0	0	0.0	0	0.0	5	146.4
Gotland 2 & 3	0	0.0	0	0.0	2	46.8	0	0.0	0	0.0	0	0.0	2	46.8
Fennoskan	0	0	0	0.0	2	18.5	1	120.7	0	0.0	0	0.0	3	139.2
SACOI[1,2]	4	7.6	0	0.0	1	5.0	0	0.0	0	0.0	4	581.0	9	593.5
New Zealand 2	0	0.0	0	0.0	1	0.7	0	0.0	0	0.0	5	9.3	6	10.0
Kontek	3	129.8	1	3.0	0	0.0	0	0.0	0	0.0	0	0.0	4	132.8
SwePol	1	1.2	2	5.2	1	0.3	0	0.0	0	0.0	0	0.0	4	6.7
Kii Channel	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Grita	1	5.8	3	6.9	5	71.2	0	0.0	0	0.0	1	2.5	10	86.4

Notes
AC-E: AC and Auxiliary Equipment; V: valves; C&P: Control and Protection; DC-E: DC Equipment; O: Other;
TL: Transmission Line or Cable
1 Continuation of outage from 2007
2 Major time cause by cable failures

These tables provide data with respect to the number and duration of outages by equipment type for the reporting HVdc systems. The data indicates that major outage time will result for the loss of a smoothing reactor (SACOI and Grita in 2007) and cable failures (Fennoskan, Kontek and Grita). To avoid extended outages demonstrated by the reported data and minimize the impact on the Island Interconnected System, the Labrador-Island HVdc Link will be equipped with a spare dc smoothing reactor and converter transformer at each site. The Attachment 2 report demonstrates the significant improvement in converter unavailability (a reduction from 3.04% with no spares to 0.21% with spares) and a significant reduction in hours per year from 266 hours/year to 18.6 hours/year. It must be noted that the Labrador – Island HVdc Link is capable of continuous operation in a monopolar mode during a smoothing reactor or converter transformer replacement. As a result, there is a loss of only the 278 MW of capacity over the HVdc Link and not the full 830 MW bipole capacity. Further, given the potential for extended repair times for the Strait of Belle Isle cable crossing, the Labrador-Island HVdc Link includes a spare submarine cable that is operated in parallel with one of the designated pole cables such that its condition is continually monitored. For a submarine cable fault, the faulted cable is detected, isolated and the HVdc Link returned to full bipole mode of operation within a five minute window. There is no long-term loss of system capacity or long-term outage of the system during the cable repair that is evident in other HVdc schemes as noted in the Table 3A and 3B data.

To limit the number and duration of outages caused by the ac and auxiliary equipment, valves, control and protection, and dc equipment noted in the data provided in Tables 3A and 3B, the design of the Labrador – Island HVdc Link utilizes redundant equipment throughout the design. Each HVdc converter is connected to an ac station configuration utilizing a breaker-and-one-third arrangement with no two components of the dc converter (converter transformer or filter bus) connected to adjacent circuit breakers such that a breaker failure results in the loss of two converter station elements. All protection equipment, both ac and dc utilizes redundant protection systems (protection group A and protection group B) each supplied from independent battery banks (battery banks A and B). Spare thyristors are utilized in the valve design such that failure of a thyristor does not result in loss of the converter valve. Station auxiliaries such as station service, cooling and pumping systems are fully redundant such that loss of one auxiliary does not result in loss of a pole. Consequently, the Labrador – Island HVdc Link design minimizes the risk of long duration outages at the converter stations through redundant systems.

With respect to the overhead line failure rates, the Attachment 2 report acknowledges that the HVdc transmission line outage statistics are not as readily available as those for ac lines. The analysis considered the outage statistics from a CIRGE compilation during the 1990's to obtain a failure rate for overhead HVdc lines. The report assumed a failure rate of 0.0191 failures/100 km/year for the bipole failure of the overhead line. With a total of 1068 km of overhead line, the bipole failure rate for the Labrador – Island HVdc Link is calculated to equal 0.204 failures per year or one failure every 4.9 years. The average duration for the overhead transmission line outage is calculated at 1.78 hours in the Attachment 2 report. This low average outage duration supports the view that major outages resulting in long outages similar to those caused as the result of a major ice and wind event would be much less frequent.

It is understood that the failure rate of the overhead HVdc line will be influenced by the line design parameters such as climatic loading conditions. While it is impossible to guarantee that a transmission line can be built and never fail due to climatic loads, application of recognized transmission line design standards using known, or prudent, climatic loading conditions result in overhead lines that minimize the risk of a structural failure and long duration outage during the transmission line design life as supported by the data and calculations noted above.

In summary, while the calculated total bipole failure rate based on available data suggests a bipole outage of, at most, once every three years, the data also suggests that the more frequent outages will be reasonably short in duration and the frequency of longer outages such as those experienced as the result of a wind and ice storm would be much lower.

With respect to outage events for the Muskrat Falls plant, it is expected that there will be less than 0.0001 hours of total plant outages per year at the Muskrat Falls Plant, where all four units are out of service, and this will not have significant impact on the overall supply to the Island.