Q. Please describe the effects on reliability with the loss of the Labrador Island Link project under one and two pole loss assumptions. In the response identify how much load may be lost under each assumption and if load is lost by a full or partial loss of Labrador Island Link project, how long it would take to restore the system from other sources.

A. Hydro has established criteria related to the appropriate reliability for the System, at both the generation and transmission levels.

For generation, these criteria set the minimum level of reserve capacity and energy installed in the System to ensure an adequate supply for firm demand; however, short-term deficiencies can be tolerated if the deficiencies are of minimal incremental risk. As a general rule to guide Hydro's planning activities, the following have been adopted:

Capacity: The Island Interconnected System should have sufficient generating capacity to satisfy a Loss of Load Hours (LOLH) expectation target of not more that 2.8 hours per year.[1]

Energy: The Island Interconnected System should have sufficient generating capability to supply all of its firm energy requirements with firm system capability.[2]

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[1] LOLH is a statistical assessment of the risk that the System will not be capable of serving the System's firm load for all hours of the year. For Hydro, an LOLH expectation target of not more than 2.8 hours per year represents the inability to serve all firm load for no more than 2.8 hours in a given year.

[2] Firm capability for the hydroelectric resources is the firm energy capability of those resources under the most adverse three-year sequence of reservoir inflows occurring within the historical record. Firm capability for the thermal resources (HTGS) is based on energy capability adjusted for maintenance and forced outages.

The combination of the Muskrat Falls generation and the Labrador-Island Link is the least cost supply alternative and satisfies the capacity and criteria well into the next decade.

At the transmission level, the following provides a summary of Hydro's Transmission Planning Criteria:

- Hydro's bulk transmission system[3] is planned to be capable of sustaining the single contingency loss of any transmission element without loss of system stability;
- In the event a transmission element is out of service, power flow in all other elements of the power system should be at or below normal rating;
- The Island Interconnected System is planned to be able to sustain a successful single pole reclose for a line to ground fault based on the premise that all system generation is available;
- Transformer additions at all major terminal stations (i.e., two or more transformers per voltage class) are planned on the basis of being able to withstand the loss of the largest unit;
- Transformer station additions at major terminal stations with a strong underlying high voltage connection, such as Oxen Pond to Hardwoods 66 kV system, are made with consideration of the total transformer capacity and available standby generation in the loop as long as the underlying system can accommodate the transfer of load between terminal stations. For single transformer stations there is a back-up plan in place which utilizes Hydro's and/or Newfoundland Power's mobile equipment to restore service, but this

[3] Hydro's bulk transmission system on the Island of Newfoundland is generally considered to be the 230 kV transmission system and the underlying 138 kV transmission loops between connection points on the 230 kV system including Western Avalon to Holyrood and Deer Lake-Stony Brook-Sunnyside.

will require an outage for mobilization, connection and energization of the mobile equipment;

- For normal operations, the system is planned on the basis that all voltages be maintained between 95% and 105% of nominal voltage (i.e., 218.5 to 241.5 kV on the 230 kV network);
- For contingency or emergency situations, voltages between 90% and 110% of nominal voltage are considered acceptable (i.e., 207 to 253 kV on the 230 kV network); and
- For new terminal stations connected to the bulk system, Hydro's preferred bus arrangement is a breaker-and-one-half scheme. Where there are a limited number of elements, a ring bus arrangement is acceptable. Conversion to a breaker and half scheme will be considered if there is known potential for additional future expansion and physical space is available.

For further clarity, the following outlines how the transmission planning criteria was applied and tested throughout the technical analysis of the Lower Churchill Project, including work completed by both TransGrid Solutions and SNC-Lavalin. The criteria were also reviewed and deemed adequate and appropriate by Manitoba Hydro International as part of its independent review of the Lower Churchill Project on behalf of the Government of Newfoundland and Labrador, completed in October 2012:

Steady State Analysis Criteria

- With all equipment in service, power flow in all transmission elements should be at, or below, normal rating;
- With a transmission element (line, transformer, synchronous condenser, shunt or series compensation device) out of service, power flow in all other elements of the power system should be at or below normal rating;

- Transformer additions at all major terminal stations (i.e. two or more transformers per voltage class) are planned on the basis of being able to withstand the loss of the largest unit, however a brief outage to facilitate isolation and switching may be required;
- For transformer station additions at major terminal stations with a strong underlying high voltage connection, consideration will be given to the total transformer capacity and available standby generation in the loop as long as the underlying system can accommodate the transfer of load between terminal stations;
- For normal operations, all voltages be maintained between 95% and 105%;
- For contingency or emergency situations, all voltages be maintained between 90% and 110%; and
- Analysis will be conducted with one, high inertia, synchronous condenser out of service at Soldiers Pond.

Transient Analysis Criteria

- System response shall be stable and well damped following a disturbance;
- System disturbances include:
  - Successful single pole reclosing on line to ground faults;
  - Unsuccessful single pole reclosing on line to ground faults;
  - Three phase faults with tripping of a 230 kV transmission line except a three phase fault on the Bay d'Espoir 230 kV bus;
  - Loss of the largest generator on line on the Island System with and without fault;
  - Line to ground or three phase fault with tripping of a synchronous condenser;
  - Fault and tripping of a series compensated, 230 kV transmission line and, if applicable, with the series compensation device out of service

on the in service parallel 230 kV transmission line;
  - Temporary HVdc pole fault;
  - Permanent HVdc pole fault;
  - Temporary HVdc bipole fault;
- Post fault recovery voltages on the ac system shall be as follows:
  - Transient under voltages following fault clearing should not drop below 70%;
  - The duration of the voltage below 80% following fault clearing should not exceed 20 cycles;
- Post fault system frequencies shall not drop below 59 Hz;
- Under frequency load shedding
  - shall not occur for loss of on island generation with the HVdc link in service;
  - shall not occur for permanent loss of an HVdc pole;
  - shall not occur for a temporary bipole outage;
  - shall be permitted, but controlled, for a permanent bipole outage; and
- There shall be no commutation failures of the HVdc link during post fault recovery.

The Labrador-Island Link (LIL) HVdc transmission system has been planned and designed based on the above criteria and for a single pole failure, there will be no customer load shedding on the Island system. For the loss of two poles on LIL, a more onerous but less frequent occurrence, controlled, under frequency load shedding will be permitted but the system will be designed with a protection and restoration system to provide an orderly restoration of affected customers utilizing Island generation and imports of up to 300 MW via the Maritime Link.

The LIL will be capable of operating in bipolar mode and monopolar mode (i.e., one pole out of service) with ground or metallic return. The system has the following characteristics:

- Rated voltage: ±350 kV dc;
- Bipolar operation:
  - Rated power at rectifier (Muskrat Falls): 900 MW (450 MW per pole);
  - Rated power at inverter (Soldiers Pond): 830 MW[4] (415 MW per pole);
  - Rated current: 1286 A per pole;
- Ten minute monopolar operation:
  - Rated power at rectifier (Muskrat Falls): 900 MW;
  - Rated power at inverter (Soldiers Pond): 662 MW;
  - Rated current: 2572 A;
- Continuous monopolar operation – earth return:
  - Rated power at rectifier (Muskrat Falls): 675 MW;
  - Rated power at inverter (Soldiers Pond): 552 MW; and
  - Rated current: 1929 A.

During normal operation with the LIL loaded to 900 MW at the Muskrat Falls rectifier, a nominal 170 MW[5] is designated for delivery to Nova Scotia with the remaining 730 MW potentially designated for delivery to the Island Interconnected System. With the LIL operating at maximum transfer, the generation on the Island Interconnected System must be dispatched to have sufficient spinning reserve to maintain system frequency for the loss of the largest hydroelectric unit (i.e., 154

[4] Actual delivered power is dependent upon overhead line resistance, which varies with ambient temperature.
[5] The Emera NL block consists of 0.98 TWh delivered in a 16 hour per day, seven day per week product. The capacity equals 167.8 MW.

MW Bay d'Espoir Unit 7) as the LIL will have no capacity remaining to supply the reserve.

For permanent loss of a pole on the LIL, the system has a ten minute, monopolar rating of 662 MW at the Soldiers Pond inverter. Under the LIL full load scenario, this will result in a 168 MW deficiency in transfer capacity when compared to the full bipole transfer capacity. However, with the loss of a pole on the LIL, in order to prevent load interruption on the Island, the export of the Emera block (nominal 157 MW) will be curtailed by an automated protection scheme leaving the full 662 MW ten minute rating of the LIL at Soldiers Pond for the support of the Island Interconnected System load. Under the LIL full load scenario after removing the Nova Scotia Block, the nominal delivery via LIL to Soldiers Pond for use on the Island in the bipole mode is 673 MW. Comparing this amount to the LIL ten minute, monopolar rating of 662 MW, results in a maximum 11 MW deficiency on the Island Interconnected System. The 11 MW deficiency would be made up by the spinning reserve on the Island Interconnected System in this operating mode thus preventing any customer load loss[6].

The ten minute overload capability on the LIL provides the Energy Control Centre with sufficient time to start off-line generation if necessary, such that, starting at the ten minute mark, over the next ten minutes, loading on the LIL at Soldiers Pond

[6] Historically, with the Island Interconnected System isolated from the North American grid, operating experience demonstrates that a 25 MW generation rejection under light load conditions does not result in under-frequency load shedding events. Consequently, with the addition of high inertia synchronous condensers included in the LIL project and 154 MW of spinning reserve on the Island, an 11 MW deficiency on the Soldiers Pond inverter during a monopole contingency will not result in loss of supply to customers as there will be sufficient inertia and governor response from the Island hydroelectric units to maintain acceptable system frequency.

is reduced from 662 MW to 552 MW (the monopole continuous rating). This additional 110 MW will be met from the 154 MW of spinning reserve at the time of the event. Following the use of this reserve, additional spinning reserve will be obtained by starting available standby plants such as the combustion turbine plants.

Once the Island and Labrador Interconnected Systems reach a steady state operating point at approximately 20 minutes post LIL pole failure, redispatch of generation is necessary to re-establish deliveries of the Nova Scotia Block on a pro-rata basis of the scheduled firm deliveries on the LIL prior to the pole outage (with the firm deliveries being the Nova Scotia Block and NL native load). With the LIL limited to 552 MW in continuous monopolar mode, the allocations become 104 MW for Nova Scotia and 448 MW for the Island Interconnected System. With the original maximum Island Interconnected System allocation via LIL being 673 MW and the continuous monopolar allocation being 448 MW, there is a maximum deficiency of 225 MW, which is covered by Island generation reserves (i.e., spinning and standby). Consequently, there is no loss of customer load as long as there is a combination of 225 MW available in spinning and standby reserves on the Island.

A full loss of the LIL, referred to as a permanent bipole failure, will result in immediate curtailment of the export of the Nova Scotia capacity and loss of a maximum of 673 MW of capacity on the Island Interconnected System. The loss of 673 MW to the Island Interconnected System will require load shedding of up to 673 MW in order to rebalance on Island generation with load and return system frequency to normal. This load shedding scheme is under study to determine appropriate trigger levels and allocation across the Island.

Once the Island Interconnected reaches a stable mode following loss of the LIL, standby Island generation, if not already on line, would be brought on line to restore load curtailed during the event. The standby generation would include:

- NLH standby combustion turbines and diesel 234.7 MW(including the new 120 MW Holyrood CT); and
- Newfoundland Power standby thermal generation 41.5 MW.

A total of 276.2 MW of standby generation, if not already on line, would be available in ten to 20 minutes.

In the event of a complete LIL outage, capacity available to supply Island load would include approximately:

- 1013 to 1043 MW of on Island hydro-electric (variation due to reservoir levels);
- 276 MW of on Island thermal generation;
- Up to 300 MW of import via the Maritime Link; and
- Potential interruptible customer loads of 60 MW or more.

Resulting in a total capacity in the range of approximately 1650 MW to 1680 MW to supply load in the event of a permanent LIL outage. Based on current load forecasts, the NLH system load will exceed 1650 MW in around the year 2025.

In the unlikely event of a sustained bipole outage during peak, the existing system with a continued 60 MW interruptible arrangement, Hydro will have sufficient installed capacity to supply full load until at least 2025. Beyond the 1650 MW load level, there are options available to supplement capacity that Hydro will explore including:

- Additional industrial and commercial interruptible load arrangements;
- Customer demand side management initiatives;
- Additional imports via the Maritime Link when existing constraints in the Maritime/New England systems are mitigated; and
- Potential on-Island capacity additions.

Hydro will continue to monitor load forecast and generation availability on an ongoing basis and make adjustments to reserve capacity as required in as cost effective manner as possible.

Further, in the event of a capacity shortfall, the *Electrical Power Control Act 1994*, Part III Power Emergencies, enables the Lieutenant Governor in Council to declare a state of emergency and appoint an emergency controller who may redirect all generation and transmission assets in the province to supply the most critical and essential loads to minimize the overall impact of any shortfall.