Q. MHI is aware that a comprehensive reliability report for the entire project has been requested from Nalcor by the Board in a letter July 12, and this document was filed August 17, 2011.

Is there an <u>operational</u> based reliability report or conceptual design document considering the forced outage rate and scheduled outage rate? Have all equipment and systems been looked at from an operations and maintenance perspective using an N-1 criteria or considering the criteria required by Nalcor? Detailed areas to be covered should include but not be limited to:

a) Are there two or three auxiliary supply feeds (station service) for the bipole? Considering a potential extensive forced outage to one feed (station service) there would be an entire bipole feed from one station service transformer for an extended period. Is this acceptable? Is there a spare station service or other alterative feed? The same question applies to the battery banks and chargers.

b) How many relay buildings are being considered in the AC switchyard of the converter station? What is the physical separation between the buildings? Are there duplicate control and protections from different suppliers?

c) Has separation of equipment and controls supplies been considered to limit the amount of power lost for any event?

d) What is the Forced Outage Rate (FOR) and scheduled outage rate target?

e) Has a design report been issued detailing all these requirements? If so please provide.

f) Is there a contingency plan in place or being considered, if the reliability criteria cannot be met? For example, documents indicate that there is one synchronous condenser (SC) provisioned as a spare. If one SC is out of service for maintenance, and a second one trips off, what are Nalcor's operating plans?

A. No operational based reliability report or similar design document has yet been completed for the project. As Nalcor is now entering the detailed design phase of the project, issues such as those identified in this question are under assessment. The following represents the current thinking within Nalcor regarding the specific operational considerations outlined in the question, and are reflective of the assumptions built into the cost estimates developed at the feasibility level for inclusion in the CPW analysis.

a) In addition to two independent station service supplies, the bipole will be equipped with a standby diesel generator. The station service supplies will be derived from the AC switchyard.

At Soldier's Pond, station service AC power is available from Western Avalon (Bay d'Espoir), Holyrood (combustion turbine), and/or Hardwoods (combustion turbine) terminal stations if the bipole is out of service.

At Muskrat Falls, station service AC power is available from the 4 units at Muskrat Falls, Churchill Falls, or from Happy Valley Goose Bay (combustion turbine).

There will be two independent auxiliary ac power supplies for each Converter Station. The same applies to the dc power supply, with two independent full capacity battery banks per Converter Station, each with its own redundant charger per battery bank.

b) Nalcor's approach is to use a single building for each ac switchyard. The building will house duplicate protection and control systems. While control equipment may be provided by a single manufacturer, protection equipment will be provided by separate manufacturers.

c) Equipment and control supplies will be independent and physically separated.

d) A forced outage rate of 0.89% has been used for planning and conceptual design purposes. Planned maintenance scheduling has not been explicitly modeled in Strategist. It is assumed that maintenance will be performed in off-peak months (April - November). A detailed review of these outage rates is ongoing by SNC – Lavalin, and the results of these studies will determine the outage rates to be used in the functional specifications. Planned maintenance scheduling will be further refined in final design once the vendor has been selected.

e) The design brief and design criteria, which will include the details of all these requirements for Converters, have not been issued yet.

f) Nalcor is of the view that the reliability criteria are reasonable and achievable. In response to the specific question regarding synchronous condensers, there will be a spare synchronous condenser. Planned maintenance will be scheduled during low HVdc power transmission periods so that a forced outage of a synchronous condenser (leaving one synchronous condenser in service) will not adversely affect system operation.

Q. Please provide a copy of the analysis that was carried out in June and July of 2010 which confirmed that the 900 MW HVDC link would require a minimum operating voltage of 320 kV as referenced in Exhibit 30, Section 4, paragraph 4.

A. For analysis the maximum HVdc system losses has been set at 10% (worst case) in order to prepare a load flow model of the scheme. It must be noted that a detailed conductor and voltage optimization will be required in final design. For analysis purposes it is assumed that the converter stations will account for 2% of the system losses. At this point in time the "largest" standard conductor in the Canadian Alcan catalog is selected. The conductor is a 55.88 mm, 91 strand, 3640 kcmil, A1 (ASC) conductor with Rdc at 20 C = 0.01568 Ω/km and a rated tensile strength of 304 kN.

There is a total of 1038 km of overhead line between Muskrat Falls and Soldiers Pond. The submarine cable across the Strait of Belle Isle is assume to be an 1800 mm^2 copper cable with Rdc at 20 C = 0.0098 Ω/km. The cable route is estimated to be 30 km in length.

The total resistance per pole equals:
Rdc at 20 C = (1038 * 0.01568) + (30 * 0.0098) = 16.5698 Ω/pole

At 450 MW per pole the pole losses, excluding the converter station losses, should be less than or equal to 36 MW. The pole current is calculated as:

$P_{loss} = I^2$ Rdc at 20˚C

36 MW = I2 (16.5698 Ω/pole)

I = 1473.9 Adc/pole

To send 450 MW/pole assuming a 1474 A pole current, the sending end voltage is calculated as:

P = I * V
450 MW = 1474 Adc * V
V = 305.2 kV

The resultant nominal 900 MW HVdc system ratings are:

- ± 320 kV;
- pole current of 1406 A; and
- losses of 41.8 MW/pole or 83.6 MW/bipole – 816.4 MW receiving end.

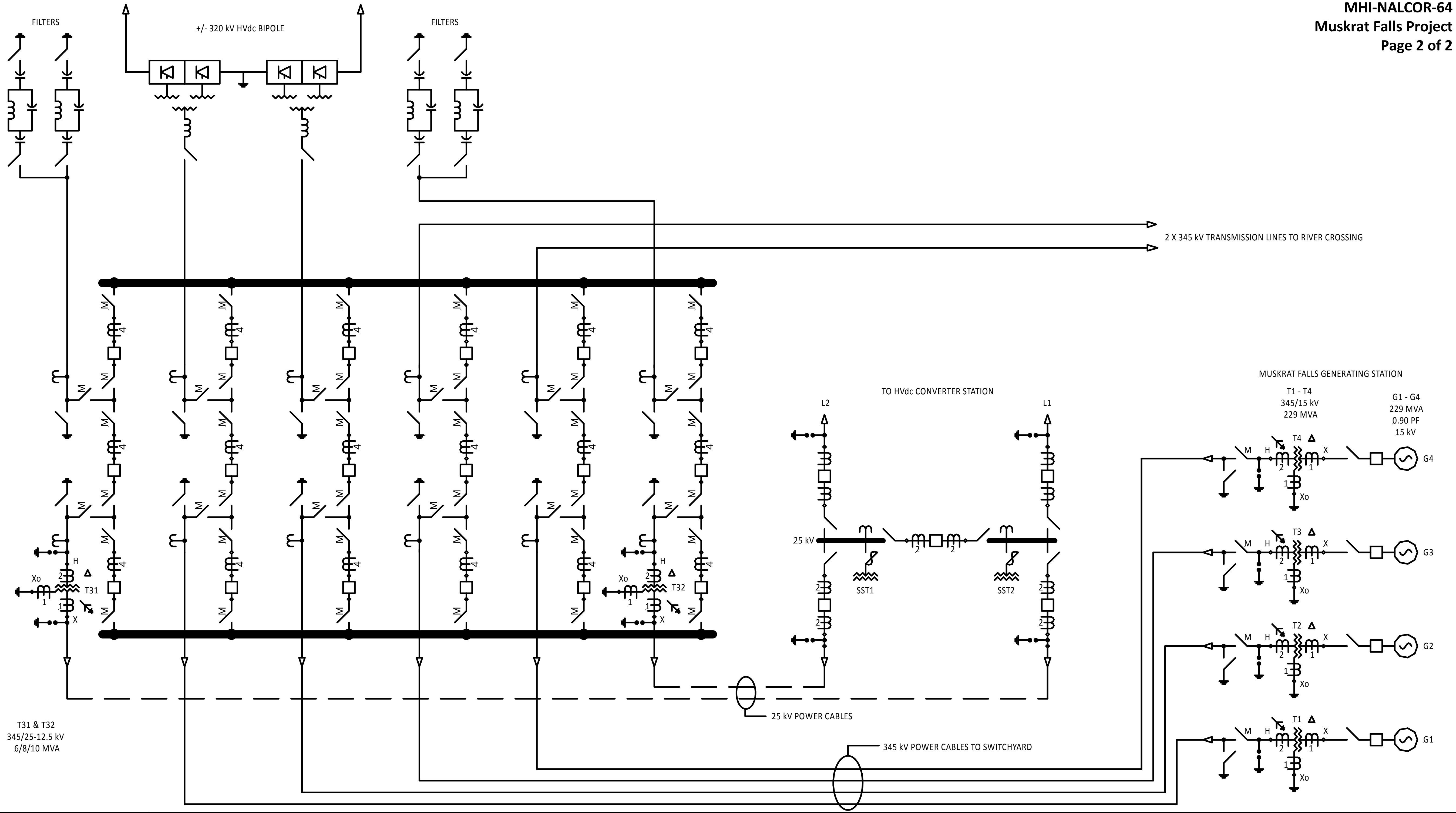
Q. In discussions with Nalcor, it was stated that the AC collector system at Muskrat Falls and associated transmission lines to Upper Churchill, was optimized at 345 kV. Please provide a document of that analysis. Please provide a copy of that analysis.

A. Please refer to the report "Preliminary Transmission System Analysis Muskrat Falls to Churchill Falls Transmission Voltage" dated November 2010 filed as Exhibit 59.

Q. Exhibit #30, page 24 shows a simplified single line diagram of the Muskrat Falls converter station. Please provide a complete single line diagram and major equipment data of the Muskrat Falls converter station.

A. A detailed single line diagram for Muskrat Falls is under development as part of detailed design and is not yet available. Detailed studies are in progress to define system characteristics that will lead to the identification of major equipment data.

A single line diagram with additional detail beyond that shown in Exhibit 30, page 24, can be found on the following page.



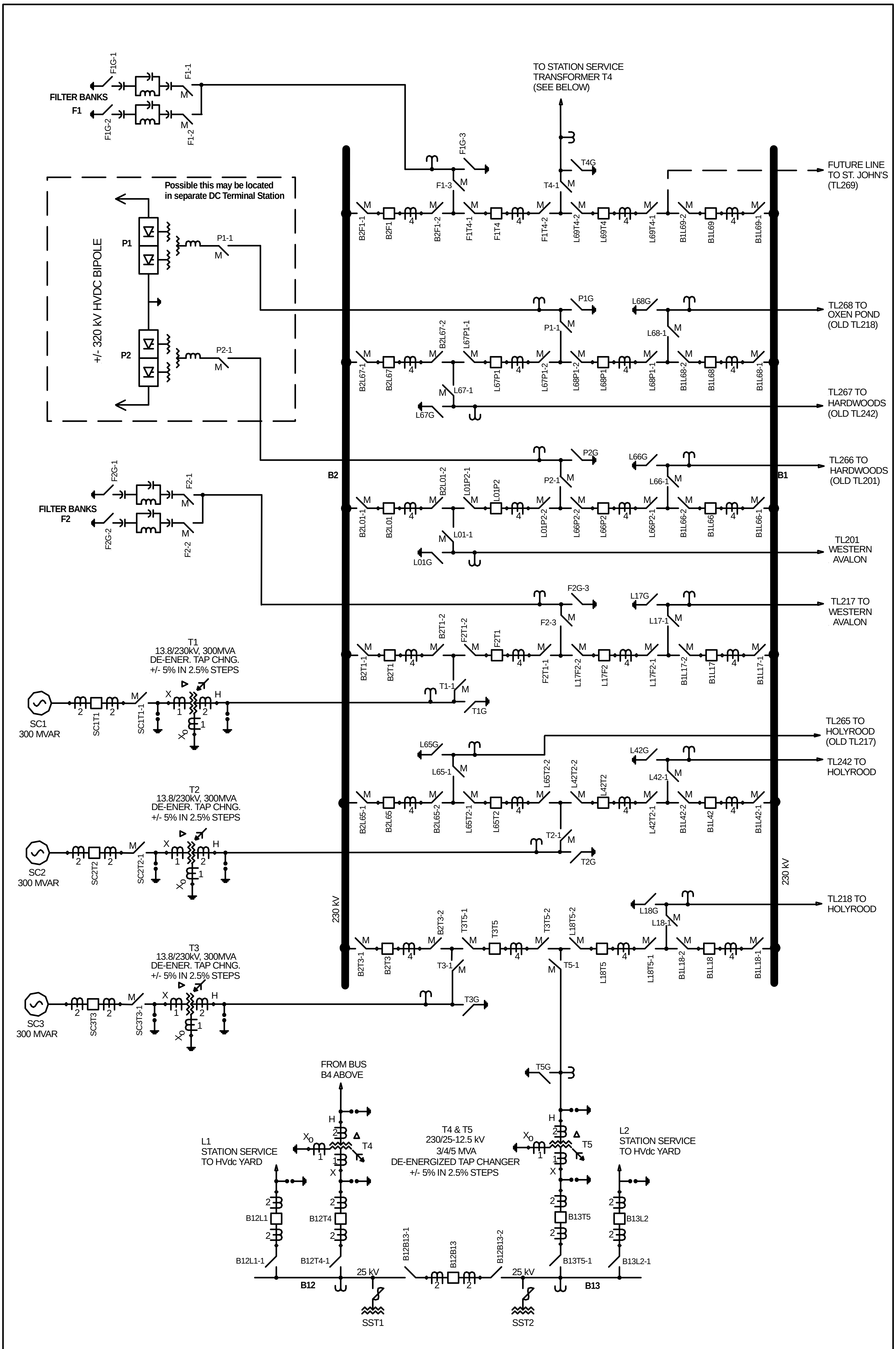
MUSKRAT FALLS AC SWITCHYARD
345 kV SINGLE LINE DIAGRAM

SYS PLAN:	SHEET 1 OF 1
SYS OP:	DATE: AUGUST 28, 2011
ELEC:	DRAWN BY: PWT
P&C:	REVISION: 0
FILE: muskrat falls ac yard.SKF	

Q. Please provide a complete single line diagram and major equipment data for the Soldiers Pond converter station.

A. A detailed single line diagram for Soldiers Pond is under consideration and is not yet available. Detailed studies are in progress to define system characteristics that will lead to the identification of major equipment data.

A single line diagram with additional detail can be found on the next page.



newfoundland labrador hydro a nalcor energy company	SOLDIERS POND TERMINAL STATION 230 kV SINGLE LINE DIAGRAM	SYS PLANNING: PWT — SHEET 1 OF 1 SYS OPERATIONS: RB/KG — DATE: JULY 22, 2011 TERM DESIGN: — DRAWN BY: JF PROTECTION: — FILE: soldiers pond 230 kv ac.SKF

Q. In discussions with Nalcor, it was stated that the Voltage Source Converter (VSC) Option was discarded and the Line Commutated Converter (LCC) chosen. One reason the VSC option was discarded was because studies showed that the recovery from a DC fault was too slow at about 900 milliseconds, and also that the system still required an Effective Short Circuit Ratio (ESCR) of 1.5. Please provide copies of the studies performed by Siemens on the HVDC Plus fault recovery rate and the ABB PSS/E ESCR study.

A. It would be incorrect to characterize the choice of technology as specifically excluding the Voltage Source Converter (VSC) option. It may be more accurate to state that, as of DG2, Nalcor has not identified a specific advantage to the use of VSC technology, and has therefore elected to adopt conventional Line Commutated Converter (LCC) technology in the Basis of Design and its capital cost estimate.

Integration studies to date (for example refer to CE-10) have demonstrated the need for high inertia synchronous condensers to prevent system collapse following a three phase fault on the 230 kV AC transmission system (excluding Bay d'Espoir) and for temporary pole to pole faults on the overhead dc transmission line. Screening level studies of the VSC option were undertaken to determine if the VSC offered performance benefits such that high inertia synchronous condenser(s) could be removed from the system, thus reducing overall project cost.

The screening studies have shown that, while the VSC will ride through the three phase 230 kV transmission system faults without the application of high inertia synchronous condensers, the VSC implementation requires the same high inertia synchronous condensers to avoid system collapse following a dc fault as were required in the LCC implementation to avoid system collapse following an ac fault. Consequently, both options require high inertia synchronous condensers to provide satisfactory system performance.

Based upon market information the Line Commutated Converter (LCC) option with high inertia synchronous condensers had a lower total cost when compared to the VSC option with high inertia synchronous condensers.

With no technical or economic benefits identified, Nalcor elected to include the LCC option in the Basis of Design and to avoid the VSC risk premium as identified in Confidential Exhibit CE-52.

Nalcor will be preparing a functional specification for the converter equipment associated with the Labrador – Island Link as part of the detailed design. Should the manufacturer(s) choose to offer a VSC option that meets the technical requirements at a lower cost than the LCC option, Nalcor will consider the VSC option for the application.

Given expected continued advancement of VSC technology, Nalcor has not ruled out VSC as a technology option, but lacking demonstrated advantages of VSC over LCC technology, has prudently included an LCC implementation for DG2. The studies undertaken by Siemens and ABB are proprietary and commercially sensitive and are not available for release.

Q. In discussions with Nalcor, it was stated that the Voltage Source Converter (VSC) Option was discarded and the Line Commutated Converter (LCC) chosen. One reason the VSC option was discarded was because studies showed that the recovery from a DC fault was too slow at about 900 milliseconds, and also that the system still required an Effective Short Circuit Ratio (ESCR) of 1.5. Please provide copies of the studies performed by Siemens on the HVDC Plus fault recovery rate and the ABB PSS/E ESCR study.

A. Nalcor has not specifically excluded the Voltage Source Converter (VSC) option. It may be more accurate to state that, as of DG2, Nalcor has not identified a specific advantage to the use of VSC technology, and has therefore elected to adopt conventional Line Commutated Converter (LCC) technology in the Basis of Design and its capital cost estimate.

Integration studies to date (for example refer to CE-10) have demonstrated the need for high inertia synchronous condensers to prevent system collapse following a three phase fault on the 230 kV AC transmission system (excluding Bay d'Espoir) and for temporary pole to pole faults on the overhead dc transmission line. Screening level studies of the VSC option were undertaken to determine if the VSC offered performance benefits such that high inertia synchronous condenser(s) could be removed from the system, thus reducing overall project cost.

The screening studies have shown that, while the VSC will ride through the three phase 230 kV transmission system faults without the application of high inertia synchronous condensers, the VSC implementation requires the same high inertia synchronous condensers to avoid system collapse following a dc fault as were required in the LCC implementation to avoid system collapse following an ac fault. Consequently, both options require high inertia synchronous condensers to provide satisfactory system performance.

Based upon market information the Line Commutated Converter (LCC) option with high inertia synchronous condensers had a lower total cost when compared to the VSC option with high inertia synchronous condensers.

Referring to page 13 of Exhibit 106, “Technical Note: Labrador — Island HVdc Link and Island Interconnected System Reliability”, the Labrador – Island HVdc Link will be required to deliver twice its nominal pole output in the event of a pole fault when the Link is running at rated output. At 900 MW and 320 kV, the sending pole will be required to deliver (900×10^6 W/ 320×10^3V), or 2,812 A during such an event. VSC systems are currently unable to deliver this current level. As a result, a VSC is unable to deliver the overload capability contemplated by Nalcor. LCC systems, however, are capable of delivering these current levels.

Given expected continued advancement of VSC technology, Nalcor has not ruled out VSC as a technology option in the future.

At DG2, however, with no technical or economic benefits for VSC technology, Nalcor elected to include proven LCC technology in the DG2 Basis of Design and to avoid the VSC risk premium as identified in Confidential Exhibit CE-52.

As requested, Nalcor has arranged release of the Siemens and ABB studies to the Board and to MHI only on a confidential basis. Please see Confidential Exhibits CE-62 and CE-63.

Q. Based on discussions with Nalcor and documents received to date, MHI understands that only $ 2.5 M has been allocated for HVDC equipment replacement / refurbishment over the 50 year life of the project. Please describe the components of this figure, and the rationale for its determination.

A. The annual operating cost estimate for the Labrador – Island Transmission Link includes an annual sustaining capital provision or allowance of approximately $1.5 million (2010 CDN $) to facilitate ongoing and regular system maintenance and refurbishment of the HVdc specialty equipment (e.g. converter station, switchyard, controls, etc.). This provision is directly for hardware replacement and excludes any technical support envisioned to be provided by Nalcor or under any master service agreement type arrangements with OEMs, which are covered as separate line items in the annual operating cost estimate. Also excluded is any sustaining capital associated with the overland transmission system or submarine cables.

This annual sustaining capital provision of $1.5 million represents an allowance only (i.e. estimate to cover the cost of known scope but with undefined requirements) that will be validated during the system and facilities studies planned to be undertaken during detailed design. For the purposes of Decision Gate 2, the basis for this allowance is assumed to be 0.25% of the estimated capital cost of the HVdc specialty equipment.

Q. From discussions with Nalcor, it is understood that some recent algorithms and custom indices have been developed to escalate the converter and other equipment costs. Please provide information on the methodologies that were used to derive these.

A. In developing an escalation model for the Project, standard indices available from Global Insight – Nalcor Energy's economic forecasting agency - were the primary source of escalation indices. Project costs were broken down into categories and matched to the best available indices. For certain specialty items and other cost categories, it was deemed necessary to use other sources or to develop custom indices that better reflected the markets for the identified items, which included:

- Subsea cables
- Turbines and generators
- Transformers
- Diesel fuel
- Labour
- Insulators
- Converter Stations

Subsea cables - Because existing indices are not representative of the market for the submarine cables required for the NE-LCP, a custom index was developed for the escalation model. This index was based on market intelligence gathered from suppliers as to what commodities and other cost items they would include in a cost escalation formula for submarine cables.

Turbines and Generators - There is no published forward looking price index that can be used to forecast the future price of large T/G sets such as those required for the Lower Churchill Project. While indices do exist for T/G sets, they are largely practical for wind and other smaller generation needs, which are significantly different than the category in which NE-LCP's needs fall. The index for T/G sets for the NE-LCP escalation model was derived from correspondence with T/G set suppliers.

Transformers - The index used for the transformers was obtained from Power Advocate. Power Advocate is an economic forecasting service that specializes in the electricity industry. They forecast price increases for commodities and have proprietary formulae for providing escalation forecasts for built items such as transformers.

Diesel Fuel - The source of the price forecast for diesel fuel was PIRA. For consistency with Nalcor's corporate cost assumptions, the PIRA index for diesel fuel was used.

Labour - To forecast cost escalation in labour costs, the annual average percentage increases from the Vale Inco Long Harbour labour agreement were used. It was determined that this agreement provided a good reflection of local labour market conditions.

Insulators - The insulator index was obtained from Power Advocate. Similar to the transformer index, the insulator index is a built-up index based on various commodities used in the manufacture of the item.

Converter Stations - There was no custom index used for converter stations. Rather, the cost breakdown from the estimate was allocated to the various cost categories and the indices were applied as was done for all other cost types.