A REPORT TO

THE BOARD OF COMMISSIONERS OF PUBLIC UTILITIES

REGISTERED PROFESSIONAL ENGINEER P. THOMAS SIGNATURE Sep 21/11 PROVINCE OF NEWFOUNDLAND	Electrical
	Mechanical
	Civil
	Protection & Control
	Transmission & Distribution
	Telecontrol
	System Planning

UPGRADE TRANSMISSION LINE CORRIDOR

Bay d'Espoir to Western Avalon

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newfoundland labrador hydro
a nalcor energy company

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1 INTRODUCTION

Newfoundland and Labrador Hydro (Hydro) owns and operates eleven 230 kV lines totaling 627 km in length connecting the Bay d'Espoir Generating Station to the major load centers and generation in the eastern portion of the province. Figure 1 provides a diagram of the Bay d'Espoir East 230 kV transmission system.

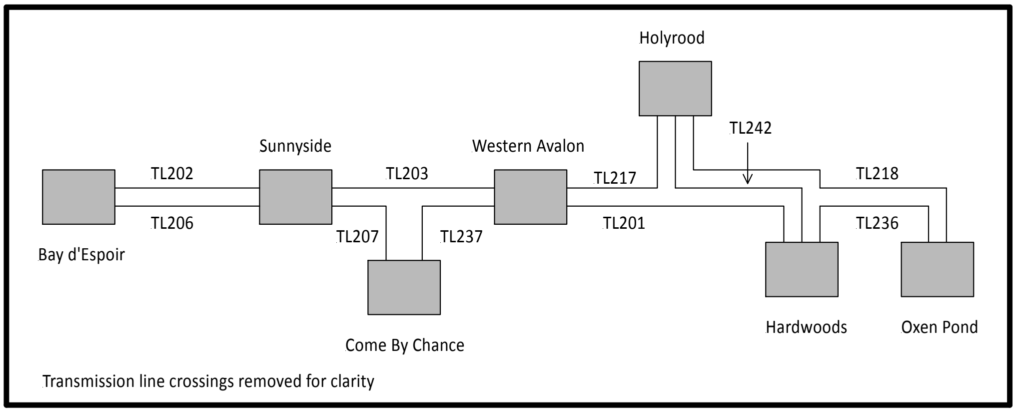

Figure 1 – Bay d'Espoir East 230 kV Transmission System

The Bay d'Espoir East 230 kV transmission system is characterized as being a heavily loaded system. Conversely, the 230 kV transmission system west of Bay d'Espoir is characterized as being a more lightly loaded system. Table 1 provides a summary of east and west loads at the time of system peaks for the period 2006 – 2010. By comparison the 230 kV transmission system east of Bay d'Espoir is loaded to approximately twice the loading of the 230 kV transmission system west of Bay d'Espoir. The heavy loading on the eastern portion of the system is coupled with the incentive to provide least-cost power to customers by minimizing Holyrood production and maximizing production from hydroelectric resources located in Bay d'Espoir and west. Constant monitoring of the load on the eastern portion of the system is therefore required. Thermal load limits on the lines must be strictly enforced to avoid unacceptable line sag and/or potential conductor damage. Further loading pressures will be placed upon the Bay d'Espoir East system with the addition of the Vale processing plant at Long Harbour and has already occurred due to the loss of load and net hydroelectric generation increase attributed to the closure of the Abitibi Bowater paper mill in Grand Falls – Windsor.

Table 1 - Bay d'Espoir East and West 230 kV Transmission System Peak Loads 2006 to 2010

Year	Bay d'Espoir – East[1]	Bay d'Espoir – West[2]
2006	836	431
2007	848	450
2008	827	436
2009	858	428
2010	833	378

Notes
1- Bay d'Espoir – East load equal to TL202 and TL206 flow plus Paradise River, Holyrood and Hardwoods generation at time of peak.
2- Bay d'Espoir – West load equal to TL204 and TL231 flow plus Cat Arm, Hinds Lake, Stephenville, Hawke's Bay, St. Anthony Diesel Plant generation and Non-Utility Generation purchases at time of peak.
3- Connaigre Peninsula loads not included
4- Values based on the Hydro Energy Management System (EMS) hourly data and not weather adjusted

Lower Churchill Impacts

Given that the Lower Churchill Project has yet to receive final project sanction, analysis of the Bay d'Espoir East 230 kV transmission system must consider both the continued Isolated Island Scenario and the Labrador Infeed Scenario. In effect, the proposed project must be appropriate to either an Isolated Island or Labrador-Interconnected future.

To accomplish this, the Bay d'Espoir East 230 kV transmission system was split into two sections – Bay d'Espoir to Western Avalon and Western Avalon to St. John's. This project considers only the upgrade requirements for the Bay d'Espoir to Western Avalon section of the Bay d'Espoir East 230 kV transmission system. The Western Avalon to St. John's section can only be considered once the decision on the Lower Churchill Project and subsequent need for the Soldiers Pond Terminal Station is made. With the final decision on the Lower Churchill Project scheduled for late 2011 or early 2012, Hydro intends to submit any necessary upgrade projects for the Western Avalon to St. John's section of the Bay d'Espoir East 230 kV transmission system associated with the proposed Lower Churchill Project to The Board as part of its 2013 capital budget application.

2 PROJECT DESCRIPTION

The Upgrade Transmission Line Corridor – Bay d'Espoir to Western Avalon project will consist of a new 230 kV transmission line, 188 km in length connecting Bay d'Espoir and Western Avalon Terminal Stations. This includes construction of a 230 kV steel tower transmission line complete with overhead ground wire over its entire length. A minimum conductor size of 795 kcmil, 26/7 ACSR "DRAKE" with a 75 ˚C conductor temperature rating or 804 kcmil 54/19 AACSR/TW with an 80 ˚C conductor temperature is required to provide the necessary thermal rating for the new circuit. At Bay d'Espoir Terminal Station, three 230 kV circuit breakers, six 230 kV motor operated disconnect switches and associated control panels will be added to complete the breaker-and-one-half arrangement on the first two legs of the station layout and accommodate the new 230 kV transmission line termination on a third leg. Figure 2 provides a single line diagram with the proposed additions in red.

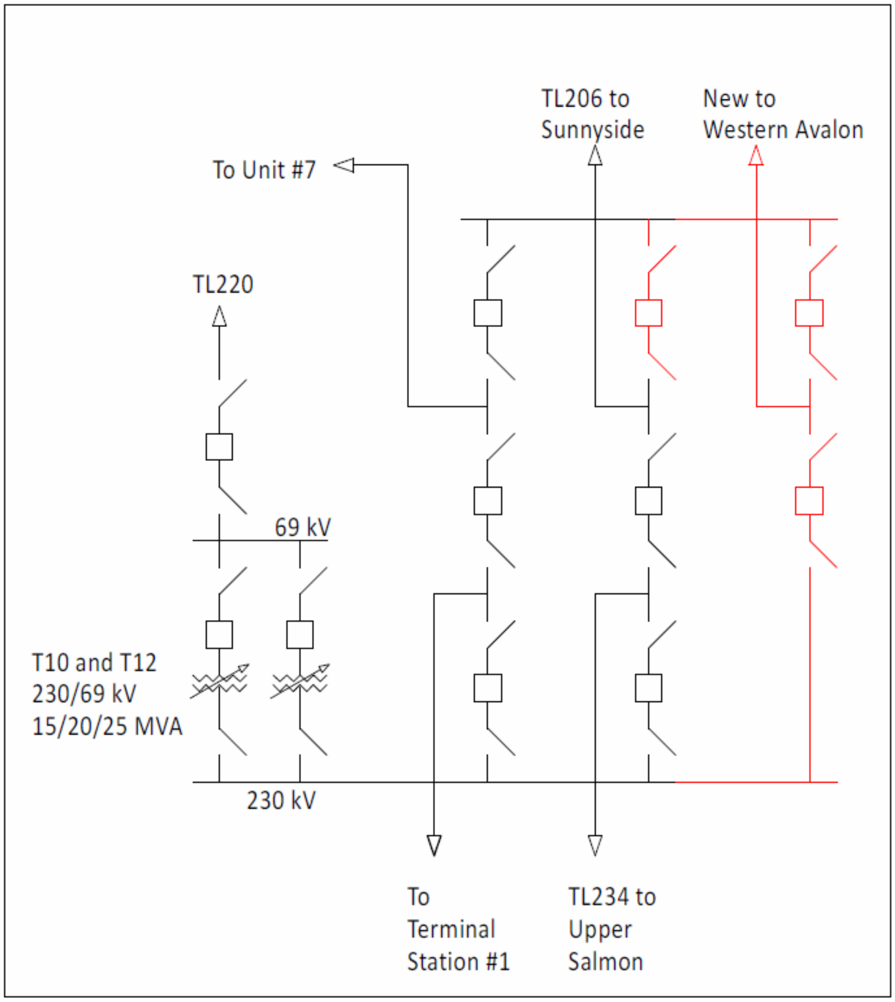

Figure 2 – Bay d'Espoir Terminal Station #2 Additions for New 230 kV Transmission Line

At Western Avalon Terminal Station a new 230 kV ring bus consisting of four 230 kV circuit breakers is proposed for the southern end of the terminal station. Rather than construct the new ring bus using traditional gas filled, air insulated circuit breakers and motor operated disconnect switches, Hydro is proposing to use a compact gas insulated switchgear (GIS) ring bus configuration. The rationale for the use of the GIS equipment is to limit the civil works for the ring bus addition. The Western Avalon Terminal Station is situated on the side of a hill near Chapel Arm. The land to the west of the terminal station consists of an upward sloping steep embankment which has had drainage issues in the past. Excavation to the west would to be extremely costly as it would require additional slope stability and drainage work along with relocation of the existing access road. The land to the east consists of a downward sloping steep embankment to Route 201. Expansion in this direction would require extensive amounts of fill. If acquisition of building lots for private homes in the area of the Western Avalon Terminal Station were to be pursued, a minimal extension to the south side of the station can be accommodated to permit installation of the compact GIS and access road realignment. As part of the GIS ring bus addition, TL208 will be re-terminated in the new ring along with the new 230 kV transmission line to Bay d'Espoir. This will improve the reliability of the TL208 supply as it will no longer be tripped due to an outage to 230 kV bus B1 or 230/66 kV transformers T1 or T2. Figure 3 provides a single line diagram of the Western Avalon Terminal Station with the proposed additions shown in red. The GIS ring bus addition will contain one spare line termination for a future 230 kV transmission line to the east, if/when it may be required. Hydro has secured the land in the area to permit the future line termination.

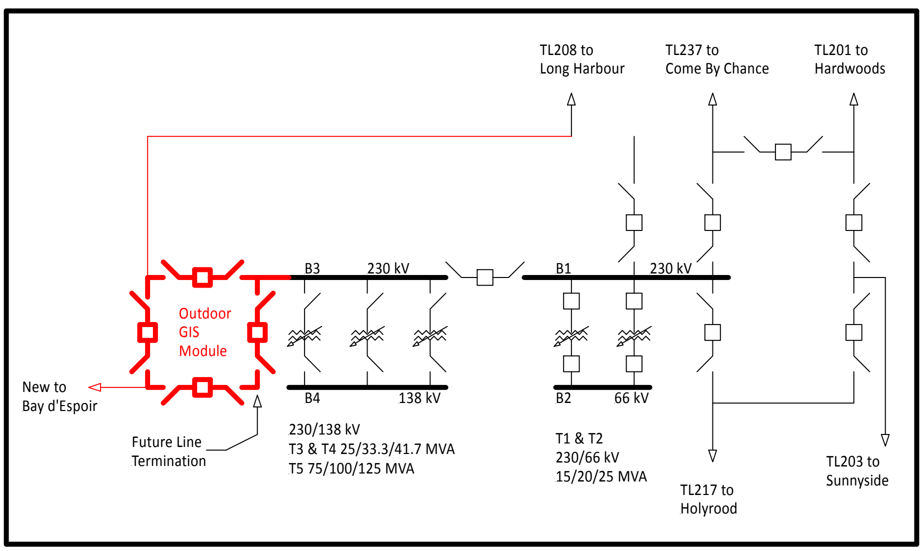

Figure 3 – Western Avalon Terminal Station Additions for New 230 kV Transmission Line

It should also be noted that this project also includes a study to investigate suspension insulators on TL206 (Bay d'Espoir to Sunnyside). These are original insulators manufactured by NEMA and are of the same vintage as the Canadian Porcelain/Canadian Ohio Brass insulators that have experienced significant cement growth and mechanical failure over time. However, there is little industry information on the long term mechanical and electrical performance of the NEMA insulators. It is suspected that the NEMA insulators on TL206 do not meet Hydro's existing suspension insulator specification. To confirm the residual mechanical strength of the NEMA insulators following 43 years in service, Hydro is proposing to remove sample strings from service and complete laboratory testing. Cost of this component is estimated at $50,000. Following testing Hydro will be in a better position to report the condition of the TL206 insulators to the Board with a recommendation on a replacement program for the NEMA insulators.

As discussed in the Justification Section below, analysis indicates that this new 230 kV transmission line is required to increase firm system capacity in both the continued Isolated Island Scenario and the Labrador Interconnected Scenario.

3 EXISTING SYSTEM

The existing Bay d'Espoir to Western Avalon transmission corridor consists of five 230 kV transmission lines including:

- TL202 – Bay d'Espoir to Western Avalon;
- TL203 – Sunnyside to Western Avalon;
- TL206 - Bay d'Espoir to Western Avalon;
- TL207 – Sunnyside to Come By Chance; and
- TL237 – Come By Chance to Western Avalon.

Table 2 provides the rating of each transmission line for varying ambient temperature.

Table 2 - Bay d'Espoir to Western Avalon Transmission Corridor Line Ratings

TL #	MVA Rating for an Ambient Temperature of			
	30 ˚C	25 ˚C	15 ˚C	0 ˚C
TL202	199.3	236.9	297.7	369.5
TL203	261.7	278.0	307.8	347.0
TL206	199.3	236.9	297.7	369.5
TL207	355.8	375.5	411.5	459.6
TL237	355.8	375.5	411.5	459.6

Of these transmission lines, TL202 and TL206 are the most heavily loaded lines during the late spring to early fall time period when the Holyrood Thermal Generating Station is shut down or operating at minimal levels. This is due to the fact that they carry the loads of both the Burin and Avalon Peninsulas along with a portion of the load on the 138 kV transmission loop between Stony Brook and Sunnyside. Load relief to TL202 and TL206 is provided by the Paradise River Hydroelectric Generating Station and the St. Lawrence and Fermeuse wind farms when in operation. Under a line-outage contingency Hydro will start its combustion turbines at Holyrood (10 MW) and Hardwoods (46 MW) to reduce the loading on the transmission corridor. Given a thermal rating of 297.7 MVA on a 15 ˚C day (i.e. spring/fall) Hydro must limit the loading on TL202 and TL206 to approximately 353 MW (297.7 + 10 + 46 = 353.7) to ensure that TL202 or TL206 does not become overloaded should TL206 or TL202 trip. Consequently for Bay d'Espoir East loads in excess of 353 MW on a 15 ˚C day, Hydro must operate generation at its Holyrood Thermal Generating Station.

This inefficiency is further illustrated in Table 3, which includes the triggers used by System Operations to determine when generators at Holyrood Thermal Generating Station are to be brought online. In an optimal situation, the generators at Holyrood would only be dispatched after all hydroelectric generators on the island are brought online (while maintaining sufficient reserve to withstand the loss of the largest unit). These optimal thresholds are indicated in Table 3.

Due to the existing thermal limitations, generators at Holyrood must be brought online at load levels that are much lower than the optimal values. The Holyrood units are therefore required to operate much earlier in the fall and later in the spring than would otherwise be required. This problem is compounded as the generators are often dispatched to produce a minimal output power (approximately 70 MW), resulting in a highly inefficient use of fuel.

Table 3 - Thresholds for Bringing Generators Online at Holyrood Thermal Generating Station

Number of Holyrood Generators In Service	Optimal Threshold to Bring an Additional Holyrood Generator Online (MW of System Generation)	Threshold to Bring an Additional Holyrood Generator Online (MW of System Generation)	Threshold/ Optimal Threshold
0*	994	635	69.2%
1*	1137	835	78.8%
2	1319	960	77.3%

* Holyrood Unit Three online as a Synchronous Condenser

While these factors demonstrate significant restrictions in the operational flexibility of the existing transmission system east of Bay d'Espoir, there is a much greater concern relating to transfer capacity. In the event of the loss of a unit at Holyrood, the existing transmission system would be unable to supply system loads above 1280 MW. While this analysis is described in detail in Section 4, it may be noted that the peak load for 2012 is forecasted to exceed 1350 MW. The loss of a unit at Holyrood would therefore result in a significant exposure for unsupplied load.

3.1 Age of Equipment or System

The 230 kV transmission lines in the Bay d'Espoir to Western Avalon corridor were built between 1965 and 1968. The original in service dates of the transmission lines are as follows:

- TL202 – Bay d'Espoir to Sunnyside – 1966
- TL203 – Sunnyside to Western Avalon – 1965
- TL206 – Bay d'Espoir to Sunnyside – 1968
- TL207 – Sunnyside to Come By Chance – 1968
- TL237 – Sunnyside to Come By Chance – 1968

3.2 Major Work and/or Upgrades

The following upgrades have occurred along the Bay d'Espoir to Western Avalon transmission corridor since installation:

Table 4 - Major Work or Upgrades

Year	Major Work/Upgrade	Comments
2003	TL203 Thermal Uprate	The thermal rating of TL203 was increased to meet system loading requirements
2002	TL237 Rebuild	Following 1994 ice storm TL237 was rebuilt for a 3 in ice load as part of the Avalon Transmission Upgrade Project
2002	TL207 Rebuild	Following 1994 ice storm TL207 was rebuilt for a 3 in ice load as part of the Avalon Transmission Upgrade Project
2001	TL206 Lightning arrester additions	Poor lightning performance of TL202 and TL206 resulted in a significant number of simultaneous outages and loss of supply to Avalon Peninsula
1993 to 1996	TL202 insulator replacements	Canadian Ohio Brass insulators replaced
1984	TL203 line upgraded with high strength 562.5 kcmil conductor	Ice storms resulted in failure of TL203 structures and outages to customers. A high strength 562.5 kcmil conductor was added to 22 km along the two-inch ice zones

3.3 Anticipated Useful life

The proposed 230 kV transmission line has an estimated service life of 50 years.

3.4 Maintenance History

As the proposed 230 kV transmission line between Bay d'Espoir and Western Avalon is a new asset, there is no maintenance history.

3.5 Outage Statistics

As the proposed 230 kV transmission line between Bay d'Espoir and Western Avalon is a new asset, there are no available outage statistics. Given the application of an overhead ground wire along its entire length, it is anticipated that the lightning performance of the new line will be very similar to that of TL206 which is equipped with lightning arresters. The mechanical and structural performance of the proposed line will be very similar to that of TL202, TL206, TL207 and TL237 as it will be designed withstand comparable meteorological loading.

Outage statistics for existing 230 kV transmission lines in the Bay d'Espoir to Western Avalon corridor are as follows:

Table 5 – Listing of Transmission Line Terminal Equipment Performance Bay d'Espoir to Western Avalon Corridor

Transmission Line	Frequency (per terminal year)	Unavailability (%)
TL202 (2006 – 2010)	0.40	0.0176
TL203 (2006 – 2010)	0.20	0.0006
TL206 (2006 – 2010)	0.00	0.0000
TL207 (2006 – 2010)	0.00	0.0000
TL237 (2006 – 2010)	0.10	0.0000
Hydro 230 kV (2006 – 2010)	0.99	0.0127
CEA 230 kV (2005 – 2009)	0.16	0.0370
Frequency (per terminal year) is the number of line outages per line terminal. Unavailability is amount of time the line is not available for terminal related causes.		

3.6 Industry Experience

As discussed in Section 4, when the load or power transfer requirements of a portion of the transmission system exceed the original rating of the transmission lines, several alternatives are considered in the industry. One alternative is to investigate the potential to increase the rating of the existing transmission lines either through re-conductoring or a combination of conductor changes (replacement or re-tensioning) and structure modifications (increases in structure height or mid span structures). The second alternative is to consider the addition of new transmission lines at the same or higher voltage to the corridor. A third alternative is to increase the voltage rating of the existing lines.

When power system stability becomes an issue along a portion of the transmission system due to changes in the system topology, generation dispatch or load patterns, the two prominent alternatives used in industry include series compensation and the construction of new transmission lines.

Series compensation involves the addition of a capacitor bank in series with the transmission line to effectively reduce its impedance. This reduction allows for the "stiffening" of the transmission network and improves stability. This technique is used extensively by Hydro-Québec TransÉnergie to increase the transmission capacity of their 735 kV network. Series compensation on the 735 kV network ranges from 16% to 50%.

The other alternative to improve power system stability is to increase the number of transmission lines and/or voltage levels in a corridor. Like series compensation, the construction of parallel lines allow reduces the overall transmission corridor impedance and thereby "stiffens" the transmission network so that it is no longer susceptible to instability.

When both transmission line ratings and power system stability issues occur along the same transmission corridor, series compensation, in and of itself, is not an effective solution on its own.

3.7 Maintenance or Support Arrangements

Normal routine maintenance work for the proposed 230 kV transmission line and associated terminal station equipment will be performed by Hydro personnel.

3.8 Vendor Recommendations

This project includes the purchase and installation of new terminal station equipment and the design and construction of a new 230 kV transmission line. Therefore vendor recommendation with respect to repair or replacement is not pertinent.

3.9 Availability of Replacement Parts

Required spare parts for terminal station equipment and transmission structure components will be purchased at the time of the equipment purchases.

3.11 Retirements

There will be no retirements as part of this project.

3.12 Safety Performance

This project is not required to comply with any specific safety regulation.

3.13 Environmental Performance

This project is not required to address any non-compliance issues pertaining to environmental regulations.

3.14 Operating Regime

The proposed 230 kV transmission line and associated terminal station equipment will be placed in service on a continuous basis, being removed only for regularly scheduled maintenance.

4 JUSTIFICATION

As indicated in Section 1, significant development east of Bay d'Espoir, particularly on the Avalon Peninsula has resulted in a shift in the province's load distribution. As a result of this shift, the limited transmission capacity east of Bay d'Espoir has become the governing factor for determining the total firm capacity of the Newfoundland and Labrador Hydro Transmission System. This limitation is demonstrated in a contingency scenario involving the loss of a unit at Holyrood over peak. As indicated in the load flow analyses below, this worst-case scenario would put a significant strain on the Bay d'Espoir East transmission system. It should also be noted that the duration of the contingency could be quite extensive if a unit at Holyrood were to be damaged or otherwise out of service.

Existing System

For the existing system, the contingency involving the loss of a unit a Holyrood is illustrated in Figure 4 where a limit of approximately 854 MW is delivered to loads east of Bay d'Espoir. As indicated in the figure, the absolute limit of the transmission system is reached in this case with gas turbines at Holyrood, Hardwoods, and the Newfoundland Power unit at Greenhill brought online for support.

It should be noted that the loss of the Holyrood unit does not result in the overloading of transmission lines in this case. Rather, the loss of the unit results in a lack of reactive power support on the Avalon Peninsula. As illustrated, Holyrood Units 2 and 3 are generating 94.8 Mvar and 103.8 Mvar, respectively, which equals their reactive power limits. If system load were to increase, these units would no longer be able to meet the reactive power consumption of the load, and the system would experience a voltage collapse.

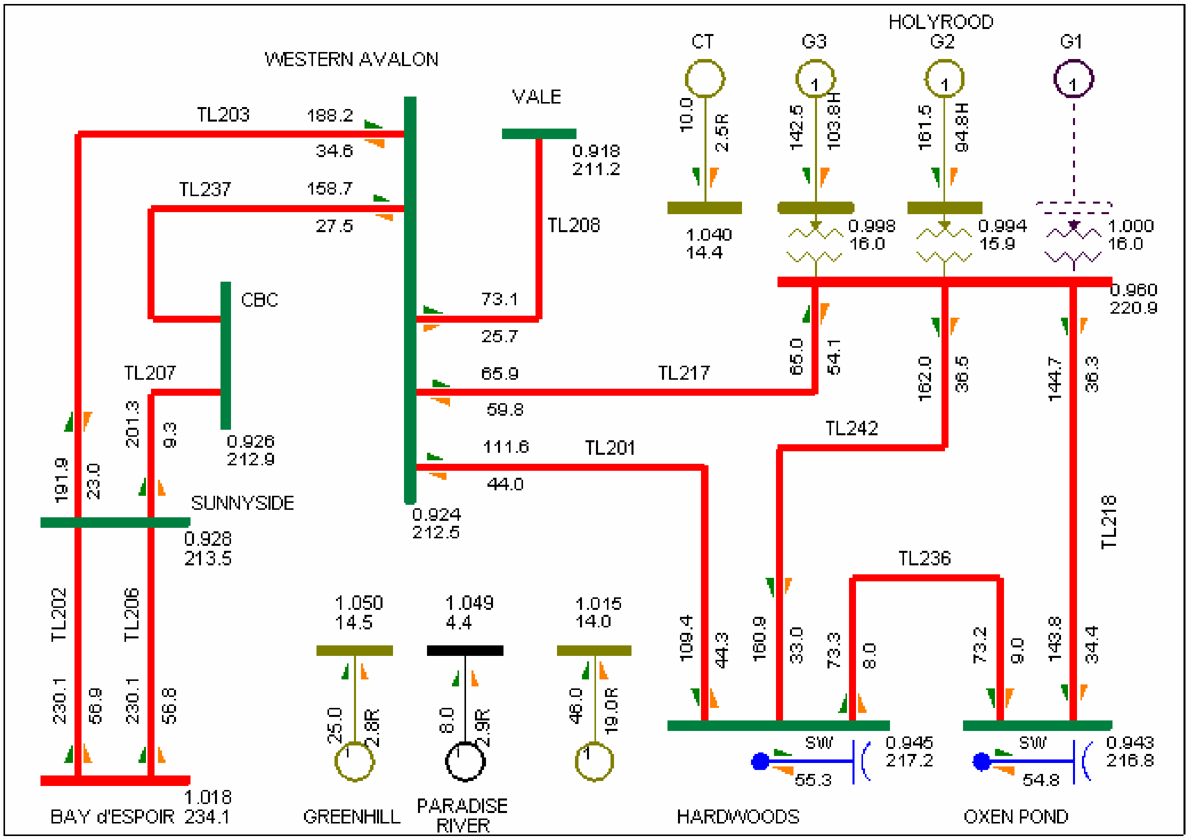

Figure 4 – Existing Transmission System – Loss of Unit 1 at Holyrood

As a result, the transmission system would only have a firm capacity of 1280 MW. As the forecasted system peak for 2012 is 1353 MW (as indicated in Section 4.6), this would result in a significant exposure for unsupplied load. This result would indicate that there is an immediate need for enhancements to the transmission system east of Bay d'Espoir.

By comparison, analysis performed in 2009-2010 indicated that this violation in the firm system capacity of the transmission system east of Bay d'Espoir would not occur until the end of the five year planning horizon. A summary of this analysis is provided in Table 6.

The next available load forecast from Newfoundland Power for use in the 2010-2011 planning and capital budget cycle revealed actual system peaks for 2010. As indicated in Table 6, these figures are higher than previously forecasted. Given the near-term violation of the firm transmission capacity criterion, a detailed investigation was performed to identify acceptable transmission system alternatives that will meet all technical requirements.

Table 6 – Forecasted Load for the Bay d'Espoir-East Transmission System

Forecast Year		2009	2010	2011	2012	2013	2014
2009-2010	Load (MW)	820	834	846	854	868	-
	Percent Loading* (%)	96%	98%	99%	100%	102%	-
2010-2011	Load (MW)	-	872	880	903	923	971
	Percent Loading* (%)	-	102%	103%	106%	108%	114%

*Percent Loading is based on an existing system capacity of 854 MW east of Bay d'Espoir.

As indicated in the following sections, the required transmission upgrades have been identified for both proposed generation expansion scenarios including a continued Isolated Island and a Labrador Infeed. These upgrades have been reviewed from a technical standpoint to ensure that the proposed solution would ensure sufficient system capacity for both scenarios.

Continued Isolated Island

Under a continued Isolated Island generation expansion scenario, the least cost hydroelectric generation sources include:

- Island Pond – 36 MW
- Round Pond – 18 MW
- Portland Creek – 23 MW

These sources are all located west of Bay d'Espoir and a continued Isolated Island scenario would therefore result in increased loading on the Bay d'Espoir to Western Avalon transmission corridor. In such a scenario, the system's existing transfer limits would not be acceptable.

No additional generation would be installed east of Bay d'Espoir in a continued Isolated

Island scenario until the 2022 timeframe when a 170 MW combined-cycle combustion turbine (CCCT) would be installed on the Avalon Peninsula. Transmission upgrades are therefore required. Alternatives for the transmission system East of Bay d'Espoir include:

(1) Performing thermal upgrades on TL202, TL206 and TL203;
(2) Installing series compensation on TL202 and TL206;
(3) Constructing a new 230 kV transmission line from Bay d'Espoir to Western Avalon Terminal Station;
(4) Installing shunt capacitor banks;
(5) Performing thermal upgrades on TL202, TL206 and TL203, installing series compensation on TL202 and TL206, and installing shunt capacitor banks;
(6) Constructing a new 230 kV transmission line from Bay d'Espoir to Western Avalon Terminal Station and installing shunt capacitor banks;
(7) Adding a 315 kV transmission line; or
(8) Adding a 315 kV transmission line and installing shunt capacitor banks.

A proposal involving only thermal upgrades on TL202, TL206 and TL203 would not improve system capacity. As demonstrated in Figure 4, system limitations for the contingency involving the loss of Holyrood Unit 1 relate primarily to reactive support on the Avalon Peninsula. Solutions involving thermal upgrades alone are only applicable after sufficient reactive power compensation has been added to the system and transmission lines become overloaded at higher system loads.

The installation of series compensation on TL202 and TL206 would help to improve transmission capacity east of Bay d'Espoir by reducing the amount of reactive power absorbed by the lines. Using the Hydro-Québec TransÉnergie system as a benchmark (as discussed in Section 3.6), an upper limit of 50% series compensation was added to each line. This level of compensation maximizes the transfer capability of the transmission system.

Figure 5 illustrates the result with 50% series compensation on TL202 and TL206. In this scenario 940 MW is transferred to loads east of Bay d'Espoir before the limits of the reactive power support on the Avalon Peninsula are reached. Loads in this case are representative of a scenario where total system generation is approximately 1410 MW. At this increased loading level, analysis indicates that no transmission line overloading would occur under any contingency. Series compensation therefore provides an increase of 130 MW in the capacity of the Island transmission system.

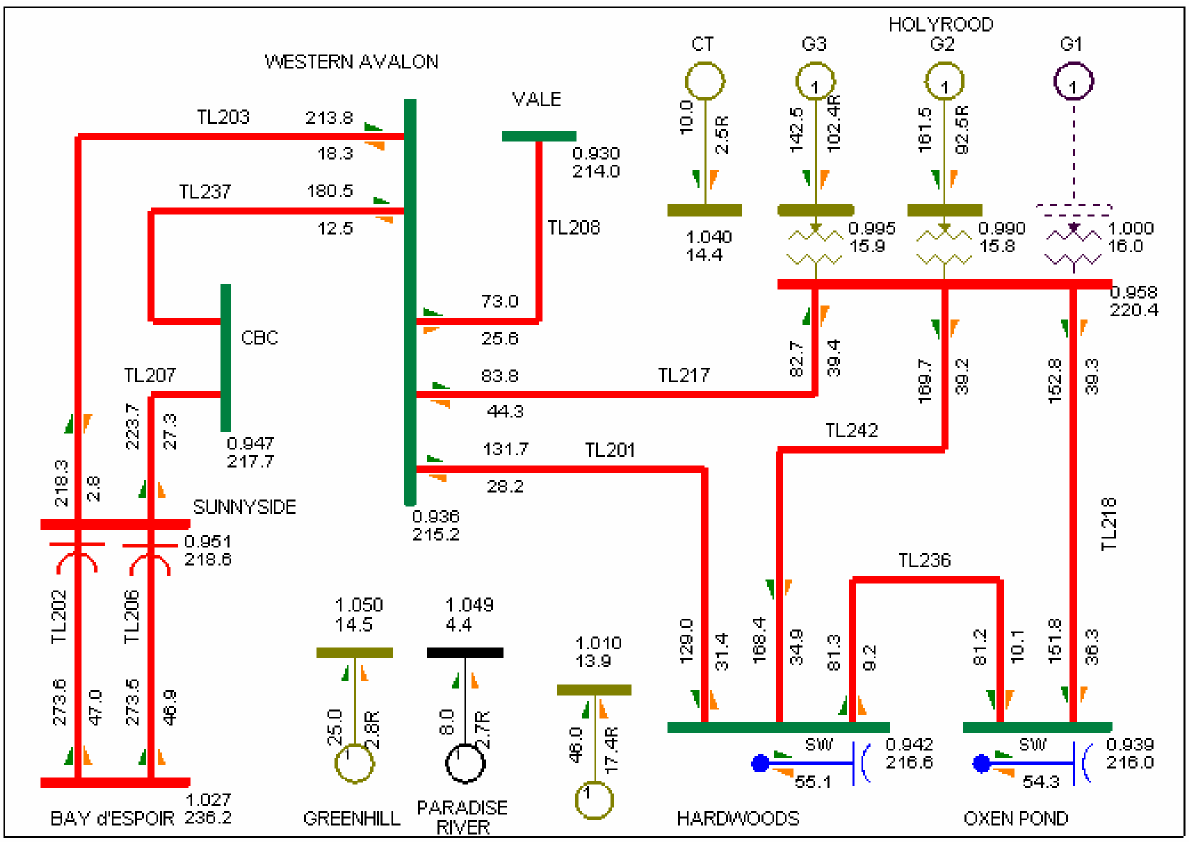

Figure 5 – Series Compensation – Loss of Unit 1 at Holyrood

Another alternative to improve the transfer capability of the existing system would involve the construction of a new 230 kV transmission line from Bay d'Espoir to Western Avalon. As illustrated in Figure 6, the Bay d'Espoir East Transmission System would be able to transfer approximately 950 MW to loads in the contingency case involving the loss of a unit at

Holyrood. This scenario is representative of a loading condition where total system generation is in the order of 1440 MW. The new transmission line would therefore increase the capacity of the existing system by approximately 140 MW.

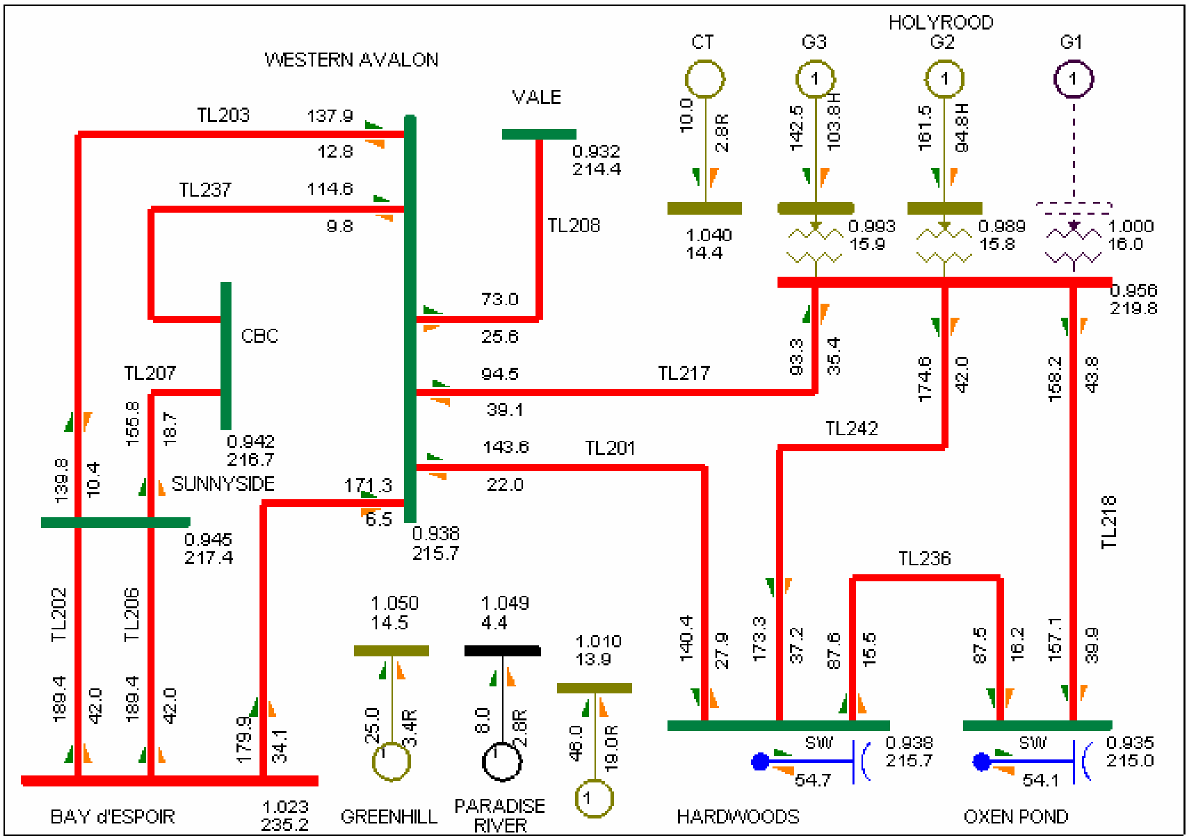

Figure 6 – New 230 kV BDE-WAV Transmission Line – Loss of Unit 1 at Holyrood

In each of the cases defined above, it is noted that the capacity of the Bay d'Espoir East Transmission System is limited primarily due to a lack of reactive power support on the Avalon Peninsula. A logical proposed would be to investigate the addition of capacitor banks as a means of avoiding voltage collapse.

The application of capacitors is illustrated in Figure 7 where a 153 Mvar bank is installed at Come by Chance Terminal Station. This site was selected at it represents one of the lowest points in the system's voltage profile and also due to the stringent undervoltage limitations required for the operation of the North Atlantic Refinery. As illustrated, this system would able to transfer 950 MW to loads east of Bay d'Espoir. It should also be noted that at this increased loading level, no transmission lines would be overloaded under contingency. From a voltage stability and thermal overload perspective, the firm capacity of the transmission system in this case would reach 1420 MW.

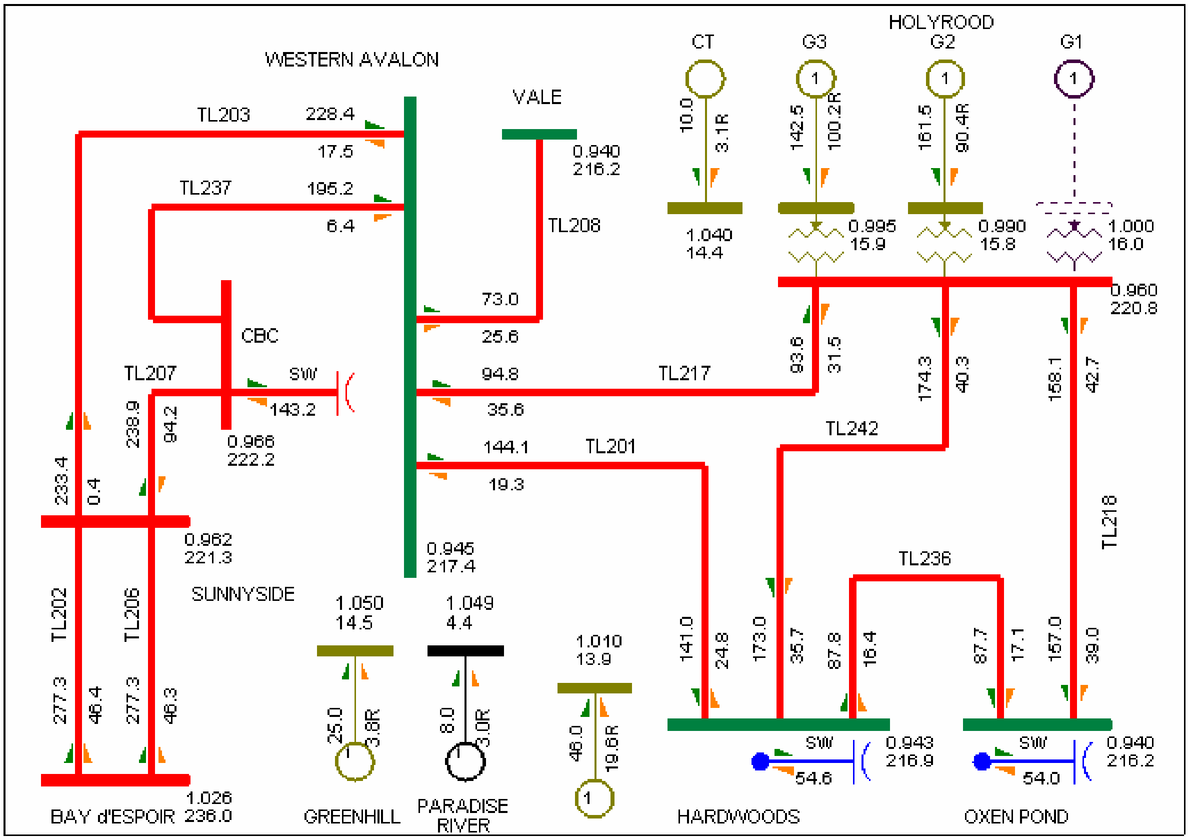

Figure 7 – Capacitor Bank Installation – Loss of Unit 1 at Holyrood

While the addition of the capacitor banks on the Avalon Peninsula would increase the voltage stability of the system by providing significant reactive power support, the system must also be designed to have an adequate angular stability. This type of stability refers to the ability of the generators within the transmission system to maintain synchronism following a disturbance. In an ac transmission system, the only way to increase the angular stability is to add transmission lines or to provide series compensation for existing lines.

A solution involving the addition of shunt capacitor banks alone would therefore not improve the angular stability of the power system. Figure 8 demonstrates the angular stability of a generator at Holyrood following a contingency involving an unsuccessful reclose for a single-line-to-ground fault event on transmission line TL202.

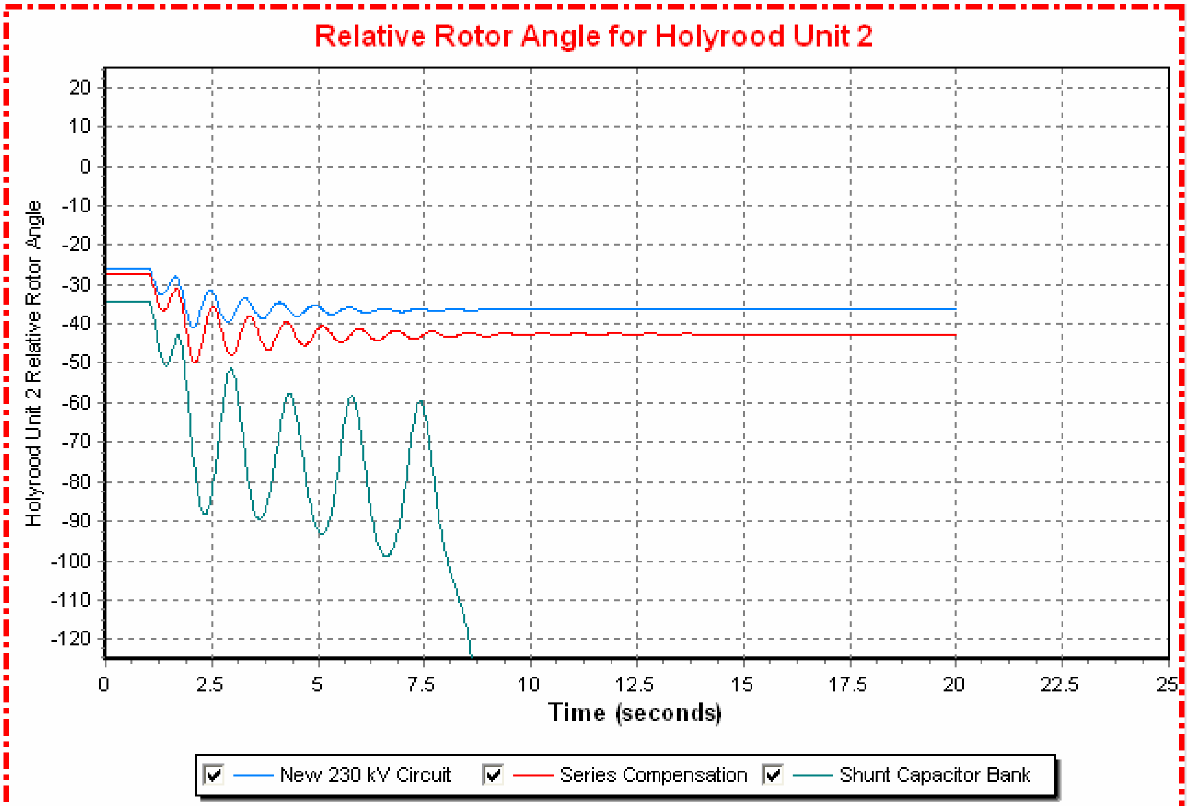

Figure 8 – Angular Stability following SLG Fault on TL202

The blue line in Figure 8 illustrates the post-fault behaviour of the Holyrood unit for the scenario where the transmission system is reinforced with the new 230 kV circuit from Bay d'Espoir to Western Avalon. As indicated, the system demonstrates angular stability as the unit quickly settles to a constant relative rotor angle. A similar result is illustrated by the red line, which demonstrates the angular stability of the system when reinforced with series compensation on TL202 and TL206.

The green line in Figure 8 indicates that the system is highly unstable in a scenario where only shunt capacitor banks are added to the transmission system. Following the fault, the unit at Holyrood would begin to oscillate uncontrollably and would have to be tripped to avoid damage. This situation would then require underfrequency load shedding in an attempt to prevent the collapse of the Island Transmission System. Due to the poor angular stability of this system, a solution involving the addition of a shunt capacitor bank alone would not be an acceptable solution.

Based on the analysis, it is evident that in order to increase the capacity of the Bay d'Espoir East Transmission System, both voltage stability and the angular stability must be improved. As noted, a combination of transmission line reinforcement and reactive support in the form of capacitor banks would provide an optimal solution.

Figure 9 illustrates a scenario involving series compensation on TL202 and TL206 and a new capacitor bank at Come by Chance. As indicated, this system allows for the transfer of 1017 MW to loads east of Bay d'Espoir. It should be noted that at this increased load level, contingencies on TL202, TL206, or TL207 would result in thermal overloading on TL206, TL202, and TL203, respectively. Thermal uprating of these lines are therefore required in this case. For TL202 and TL206, thermal uprating would require the installation of mid-span structures and the modification of terrain in the transmission line right of way. For TL203, uprating would require that the full line (44 km) be re-conductored with 795 kcmil, 26/7 ACSR "DRAKE" with additional mid-span structures or 804 kcmil 54/19 AACSR/TW with additional mid-span structures and modifications to dead-end structures. With the 795 conductor, TL202, TL206, and TL203 will each be rated for a conductor temperature of 75˚C. The 804 conductor option will allow for TL203 to be rated for a conductor temperature of 80˚C.

Total system generation in this case would be in the order of 1485 MW. While this would represent an increase of 235 MW in firm transmission system capacity over the existing system, this solution would not be adequate to meet capacity requirements beyond 2017. As additional generating capacity would not be added east of Bay d'Espoir until 2022, this solution would not provide an acceptable technical alternative.

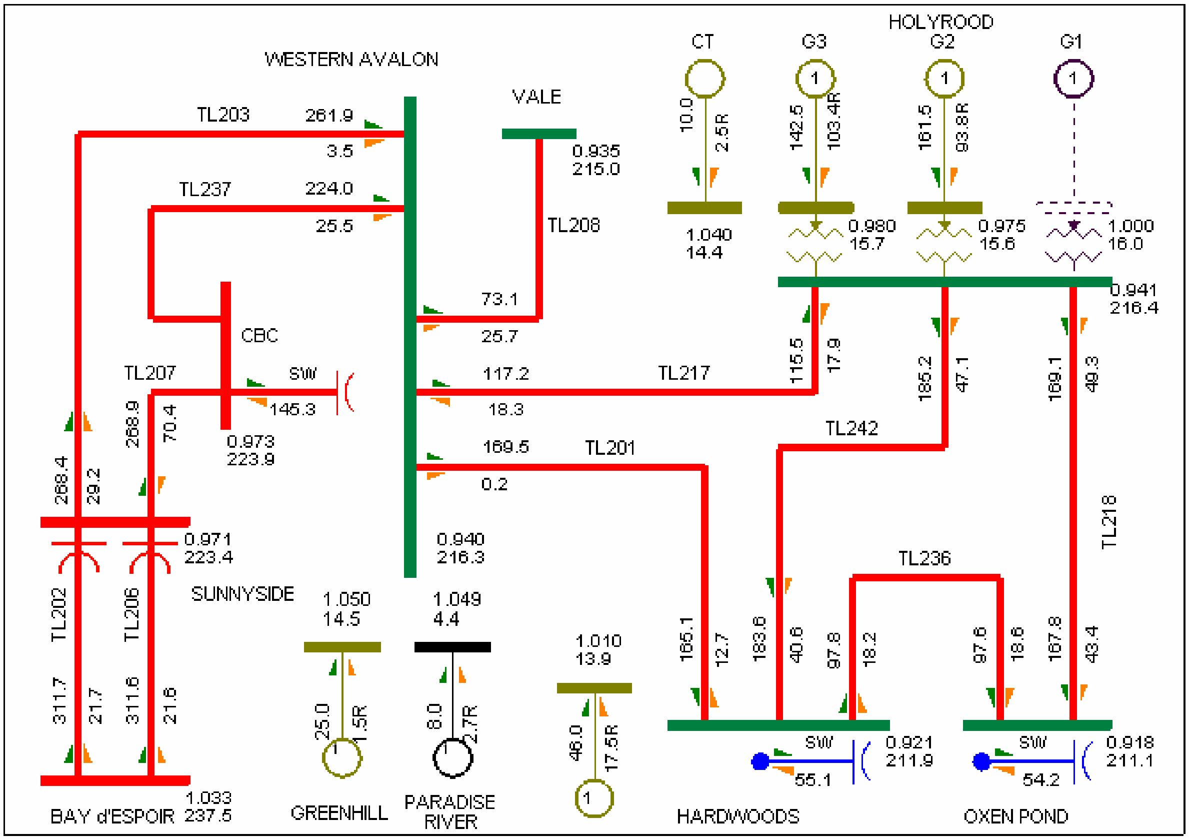

Figure 9 – Series Compensation, Thermal Upgrades, and Capacitor Bank

Loss of Unit 1 at Holyrood

The scenario involving the addition of a new 230 kV transmission line from Bay d'Espoir to Western Avalon and a capacitor bank at Come by Chance is illustrated in Figure 10. In this case, the transmission system is capable of providing firm supply of approximately 1045 MW to loads east of Bay d'Espoir. System generation in the case would be in the order of 1555 MW, which would indicate that these upgrades would increase the firm capacity of the transmission system by 275 MW. The addition of the third line would also allow for the thermal uprating of transmission lines TL202, TL206, and TL203 to be avoided. The alternative also ensures sufficient transmission capacity until 2022, at which point and 170

MW of generation would be available on the Avalon Peninsula following the construction of a new 170 MW CCCT.

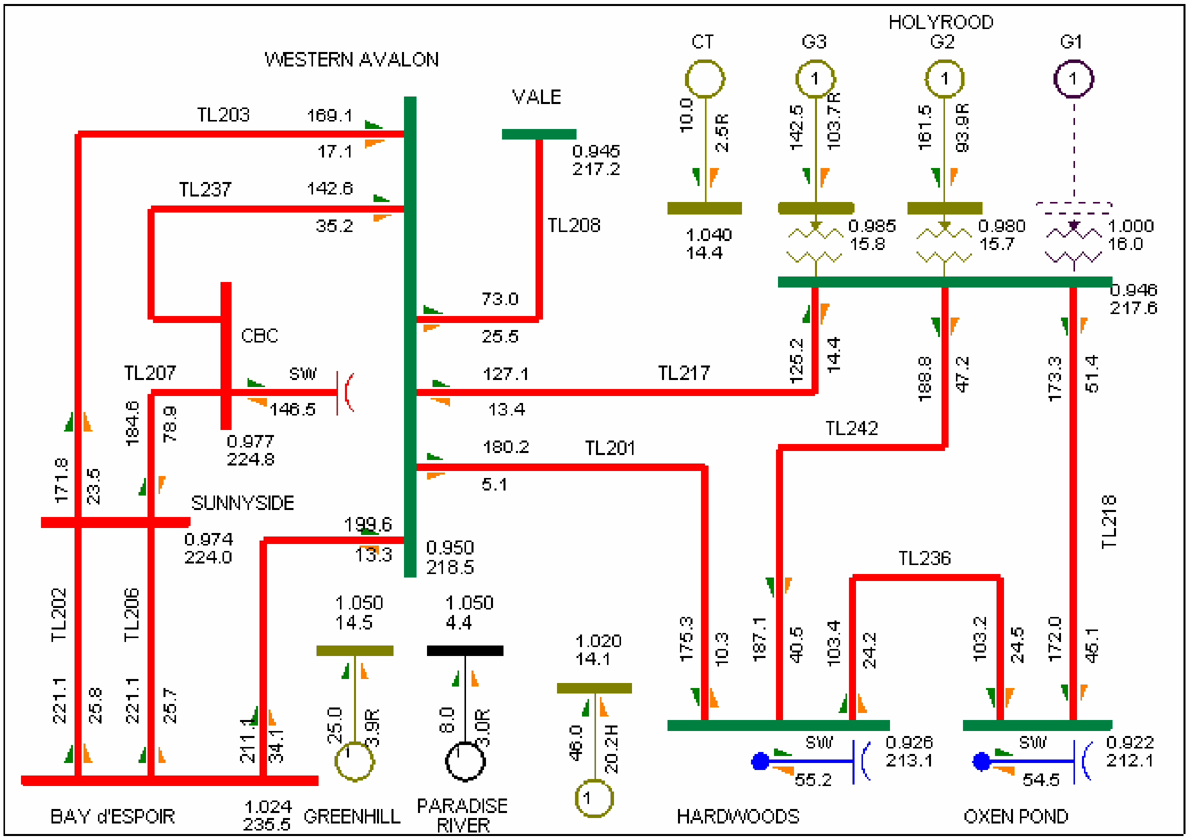

Figure 10 – New 230 kV TL and Capacitor Bank – Loss of Unit 1 at Holyrood

As part of the investigation, solutions involving the increase of the system voltage in the Bay d’Espoir to Western Avalon transmission corridor were also considered. Specifically, analysis was performed involving a new 315 kV line from Bay d’Espoir to Western Avalon.

Results of this analysis indicate that the addition of a transmission line at this voltage would increase in the transfer capacity of the system only slightly beyond the thresholds reached in the previous example. As illustrated in Figure 11, the addition of the 315 kV transmission line would not allow for an appreciable increase in transfer capacity over the case involving a new 230 kV transmission line. Due to reactive power limitations of the system, the transfer limit of the Bay d'Espoir East Transmission System is limited to 950 MW. Firm total system capacity is therefore limited to approximately 1440 in this case.

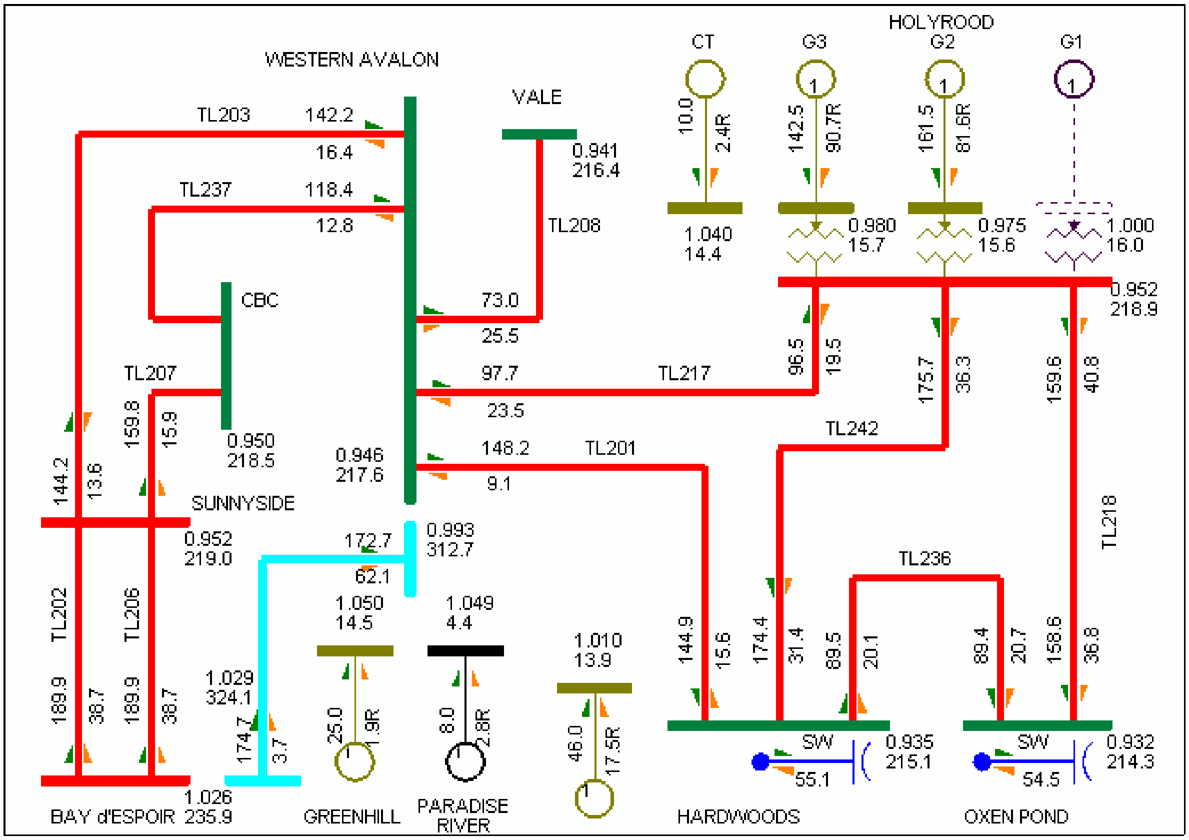

Figure 12 – New 315 kV Transmission Line – Loss of Unit 1 at Holyrood

If a new 315 kV circuit were to be supplemented with a capacitor bank at Come By Chance, approximately 1065 MW to be transferred to loads east of Bay d'Espoir, as illustrated in Figure 12. This would be representation of a loading condition where system generation has reached approximately 1583 MW.

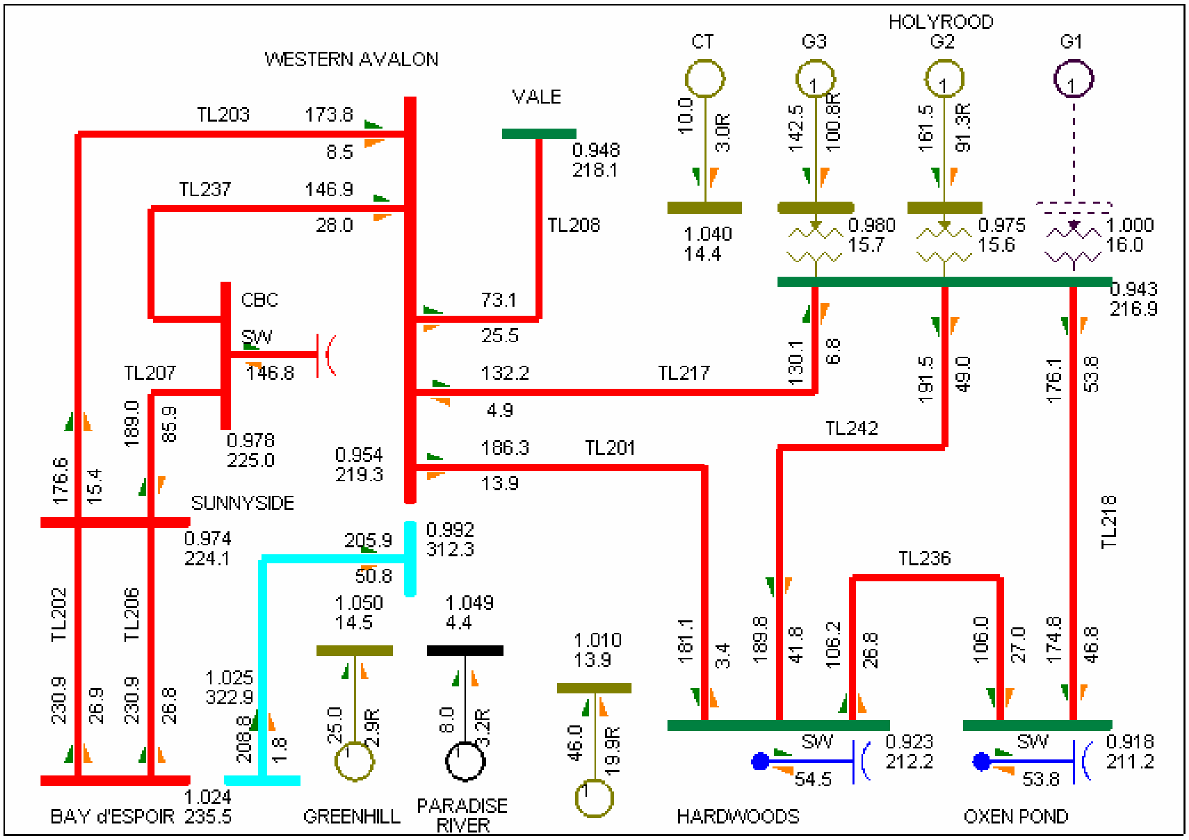

Figure 12 – New 315 kV TL and Capacitor Bank – Loss of Unit 1 at Holyrood

It should also be noted that the establishment of the 315 kV transmission voltage would require fully redundant 230/315 kV transformation at both Bay d'Espoir Terminal Station #2 and Western Avalon Terminal Station, complete with 315 kV circuit breakers and disconnect switches. Such an addition would also require the complete set of terminal station additions described above in Section 2 to permit the interconnection of 315 kV infrastructure to the existing stations. In combining this extensive listing of terminal station upgrades to the increased construction cost of a 315 kV transmission line, this solution would involve an increased capital expenditure without providing a substantial improvement in system capacity beyond those provided by the 230 kV alternatives discussed above.

Based on the results presented, it is concluded that an optimal solution for improving transmission system capacity would involve a combination of transmission line reinforcement and reactive support. A solution involving only reactive support would not be acceptable due to poor angular stability, while a solution involving only thermal upgrades would not improve system capacity. Reinforcements in the form of series compensation or a new transmission line would therefore be required.

Solutions involving the series compensation do not provide sufficient system capacity beyond 2017 and are not acceptable given that no generation will be added east of Bay d'Espoir until 2022. Therefore, a new transmission line should be constructed from Bay d'Espoir to Western Avalon to meet the 2022 transfer requirement. Both the 230 kV and 315 kV transmission line alternatives were considered. It has been determined that solutions involving 315 kV transmission lines require a significant number of additional system upgrades while only provided marginal improvements in system capacity. Given this result, the construction of a new 230 kV transmission line is found to be the optimal solution for a generation expansion scenario involving the continued Isolated Operation of the Island System.

Labrador Infeed

Under the Labrador Infeed generation expansion scenario the concept includes a 900 MW HVdc transmission system between Muskrat Falls in Labrador and Soldiers Pond on the Avalon Peninsula and a second 500 MW HVdc transmission system between western Newfoundland (Bottom Brook Terminal Station) and Cape Breton, Nova Scotia. The power and energy delivered to the Island from Labrador will displace that generated at the Holyrood Thermal Generating Station. Up to 816 MW will be delivered to the Island over peak. The HVdc system to the Maritimes will operate as an export line under normal operation with power and energy in excess of the Province's needs being sold to the Maritime and New England markets. For loss of the HVdc system between Labrador and the Island, the HVdc link to the Maritimes will be capable of delivering up to 475 MW to the Island in the post contingency period.

As part of the preliminary technical feasibility analysis performed for the Lower Churchill Project, a series of integration studies have included investigations of the upgrades required within the Island Transmission System to ensure reliability and security of supply for the Project. In these studies, many contingencies were investigated. A benchmark case was chosen to assess transient system stability in the event of a three-phase fault near the 230 kV bus at Sunnyside Terminal Station. This three-phase fault was identified as being particularly severe as it would (1) suppress ac system voltages to a point where the HVdc link from Labrador would experience a commutation failure (effectively causing it to shut down during the fault), while (2) impacting the transmission of power from hydroelectric sources to the significant loads in the eastern portion of the province.

Results of the transient stability studies indicate that the system would be able to withstand the three-phase fault at Sunnyside Terminal Station with appropriate system upgrades. The upgrades include the installation of high-inertia synchronous condensers and either:

(1) series compensation on TL202 and TL206; or
(2) a new 230 kV transmission line from Bay d'Espoir to Western Avalon Terminal Station.

Stability plots for the above cases are provide in Figures 13 and 14, respectively.

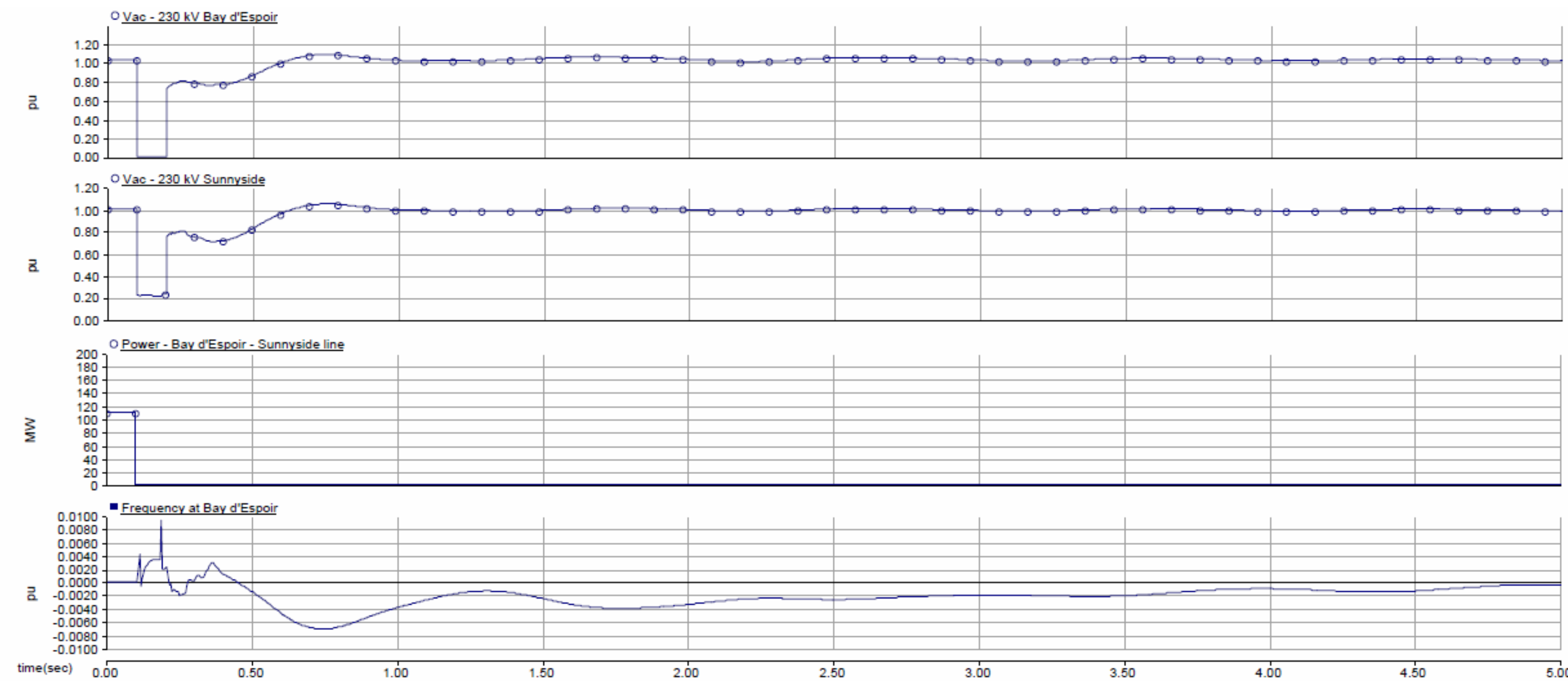

Figure 13 – Stability Plot from DC1210 - HVdc System Sensitivity Analysis Three-Phase Fault on TL202 – Series Compensation on TL202 and TL206

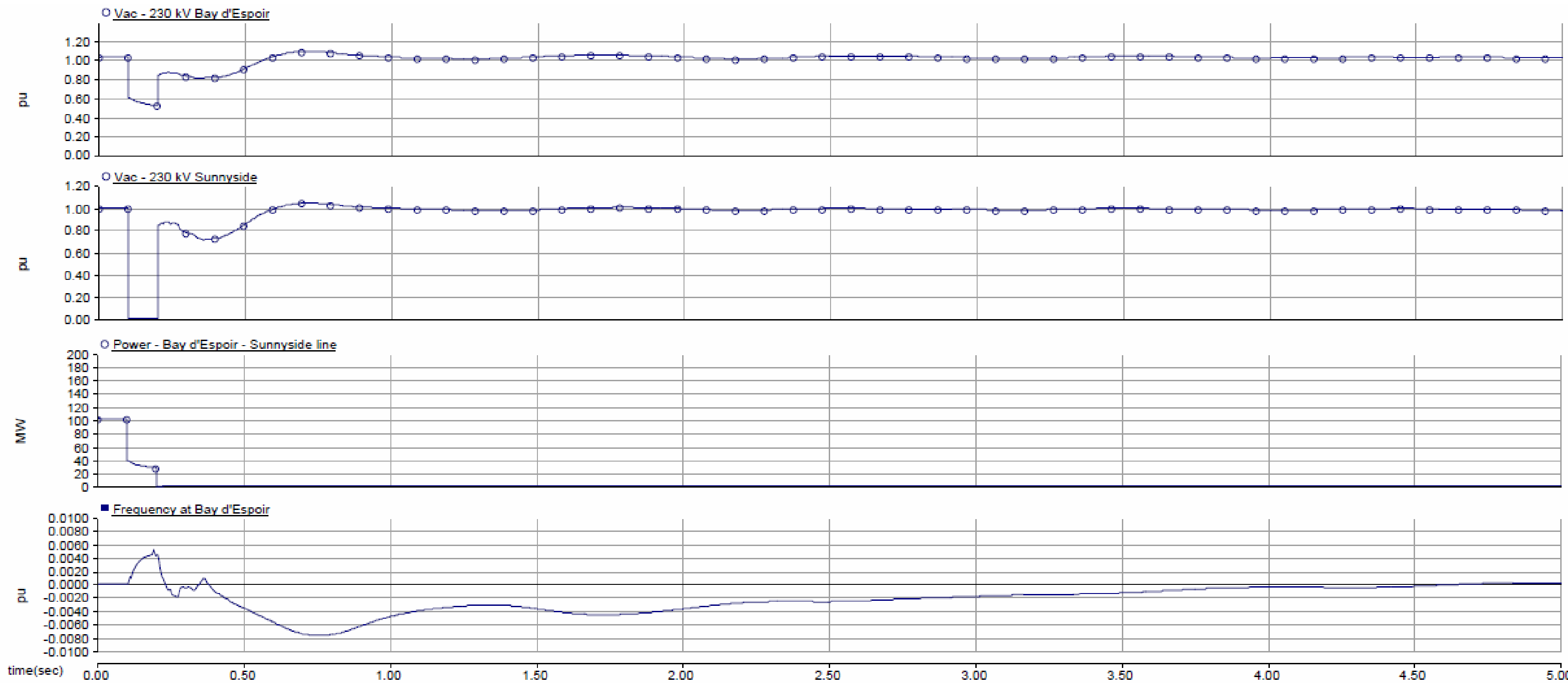

Figure 14 – Stability Plot from DC1210 - HVdc System Sensitivity Analysis Three-Phase Fault on TL202 – New 230 kV Transmission Line from BDE-WAV

While each of these alternatives ensures transient stability for specified 230 kV system contingencies, the transmission capacity of the Bay d'Espoir to Western Avalon corridor also has a significant impact in a scenario involving the loss of the HVdc link between Labrador and the Island. For this contingency, power will be imported from the Maritimes to supplement the startup of standby generation on the Island.

As in the continued Isolated Operation, Island System upgrades consisting of series compensation for transmission lines TL202 and TL206 will increase the angular stability of the power system, as illustrated in Figure 13. However, unlike the continued Isolated Operation scenario, the Holyrood Thermal Generating Station is not available to provide active power (MW) to the Bay d'Espoir East Transmission System in the Labrador Infeed Scenario. As a result, contingencies involving the loss of the Labrador Infeed would result significant overloading on the transmission lines, and therefore require the thermal uprating of TL202, TL206, and TL203.

Despite these thermal upgrades, analysis has indicated that thermal overloading will occur on TL202 and TL206 following the loss of the HVdc link from Labrador. Figure 15 illustrates the case where all generation on the island is brought online and a full import of 475 MW is received from the Maritimes following the loss of the HVdc link from Labrador. In this case, 1060 MW is being supplied to loads east of Bay d'Espoir. As illustrated, the uprated TL202 and TL206 will be loaded to 107% of their rated limits. This will result in the sagging of the transmission lines beyond Newfoundland and Labrador Hydro's clearance requirements. Such violations are unacceptable as they could lead to potential safety concerns. Analysis indicates that thermal overloads will be experienced on TL202 and TL206 if the import from the Maritimes were to exceed 440 MW.

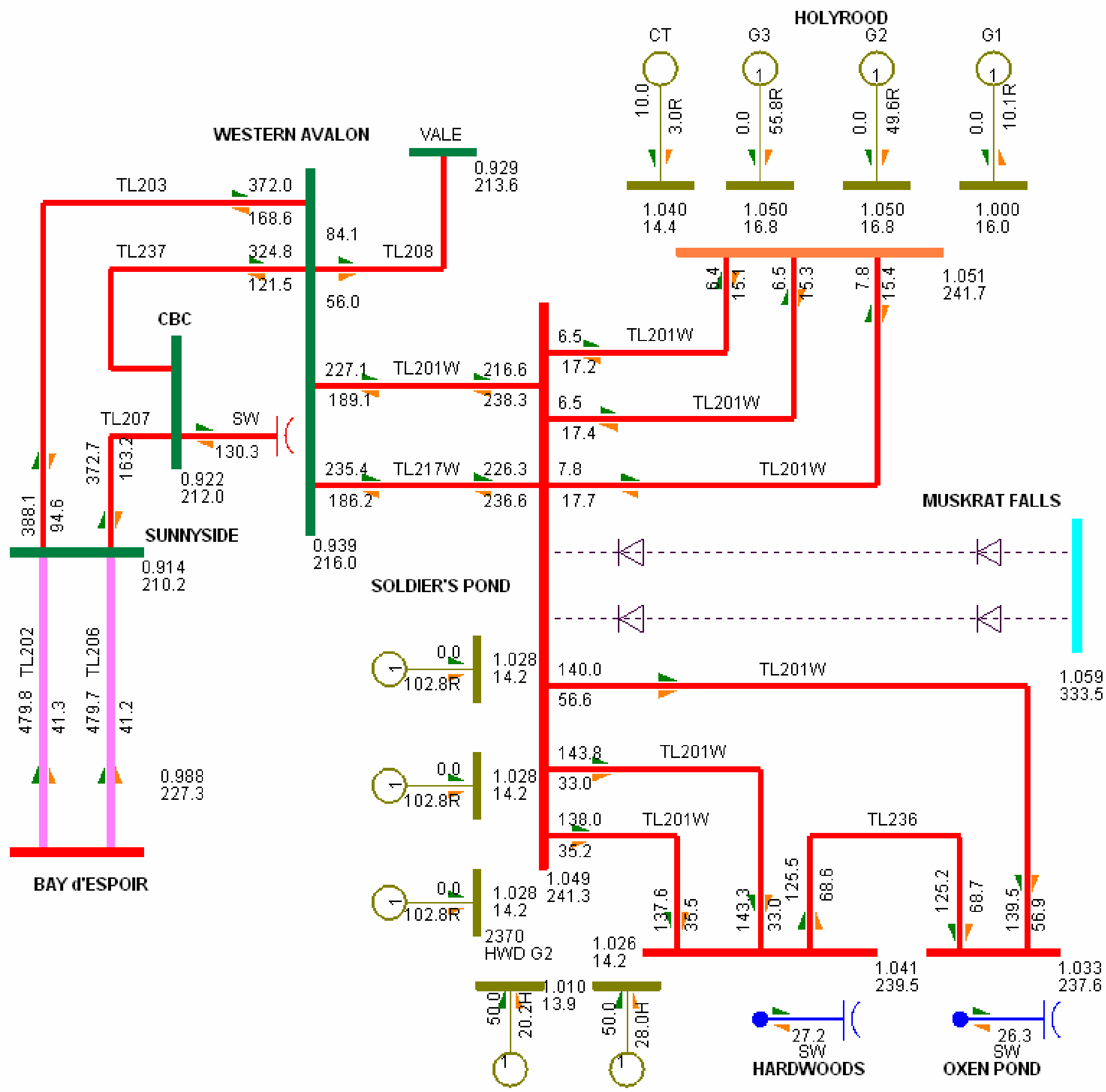

Figure 15 – Thermal Upgrades and Series Compensation – Loss of HVdc Infeed

Figure 16 demonstrates how the addition of the new 230 kV transmission line between Bay d'Espoir and Western Avalon results in the elimination of all transmission line overloads. This solution will allow for firm transmission system capacity in excess of 1600 MW in the event of the loss of the Labrador Infeed without any thermal upgrades to TL202, TL206, or TL203.

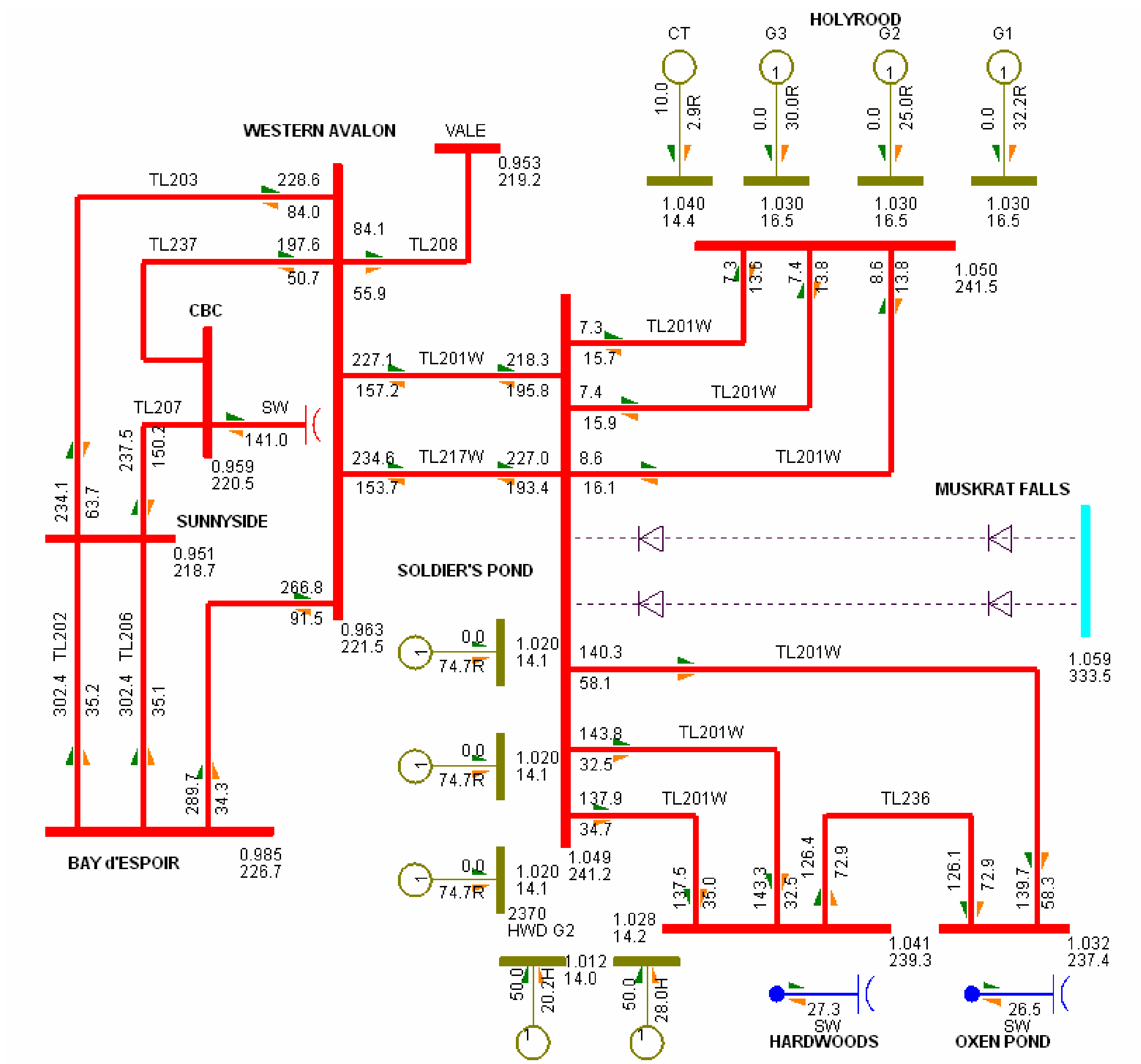

Figure 16 – New 230 kV Transmission Line – Loss of HVdc Infeed

It should be noted that reactive compensation in the form of a 153 Mvar capacitor bank at Come by Chance was included in both of the cases described above. Without this capacitor bank, the system would suffer from low voltage violations in the event of the loss of the Labrador Infeed. This capacitor bank can be considered part of the overall reactive power requirements of the HVdc converter station in this scenario.

Based on the analysis, it is concluded that a new 230 kV circuit from Bay d'Espoir to Western Avalon meets all of the technical requirements for the Labrador Infeed Scenario.

This new circuit ensures transient stability during severe ac contingencies and security of supply in the event of the failure of the HVdc link from Labrador. In order for this transmission line to be in service prior to the proposed HVdc interconnection in 2017, line construction must begin in 2012 as per the five-year project schedule provided in Section 5.2.

Analysis of the thermal upgrades plus 50% series compensation on TL202 and TL206 indicate that the option cannot provide the transfer capacity required to supply the loads east of Bay d'Espoir in the event of the failure of the HVdc link from Labrador.

4.1 Net Present Value

The construction of a new 230 kV transmission line from Bay d'Espoir to Western Avalon Terminal Station is a technical requirement needed to meet the forecasted system loads east of Bay d'Espoir. A complete net present value analysis was not performed as the project is required in both the Labrador Infeed and continued Isolated Operation generation expansion alternatives. As a result of being common to both alternatives, the cost of the project has no relevant impact on overall cumulative present worth.

4.2 Levelized Cost of Energy

The levelized cost of energy is a high level means to compare costs of developing two or more alternative generating sources. Therefore, the levelized cost of energy is not applicable for the project.

4.3 Cost Benefit Analysis

The new 230 kV transmission line from Bay d'Espoir to Western Avalon Terminal Station is a technical requirement needed to meet the forecasted system loads east of Bay d'Espoir. A complete cost benefit analysis was not performed as the project is common to both the

Labrador Infeed and continued Isolated Operation generation expansion scenarios.

4.4 Legislative or Regulatory Requirements

This project is not required to comply with legislation or regulations. The project is required to ensure reliable operation of the power system and to supply forecasted loads east of Bay d'Espoir while adhering to all system planning criteria.

4.5 Historical Information

The proposed project is not routine and is a technical requirement to meet load growth east of Bay d'Espoir for the Labrador Infeed and continued Isolated Operation generation expansion scenarios.

4.6 Forecast Customer Growth

The 2010 Peak Load Forecast for the Newfoundland and Labrador Hydro System is provided in Table 7. This forecast is equal to the 2010 Peak Load Forecast for the Interconnected Island System minus generation from Newfoundland Power and Deer Lake Power.

Based upon the peak system load data presented in Table 1, it is estimated that loads east of Bay d'Espoir will account for approximately 67% of the total system load. These values have been corrected to account for additional load associated with the Vale facility in Long Harbour and also for the reduced system losses in cases involving the construction of a new transmission line from Bay d'Espoir to Western Avalon. This reduction in losses would effectively decrease the required transfer capacity east of Bay d'Espoir.

Table 7 – 2010 Newfoundland and Labrador Hydro System Peak Load Forecast

Year	NLH System Generation (MW)	Required BDE-East Transmission System Capacity (MW)	Required BDE-East Transmission System Capacity (With New TL) (MW)
2011	1320	880	865
2012	1353	903	888
2013	1383	923	908
2014	1448	971	956
2015	1465	998	983
2016	1477	1009	994
2017	1486	1015	1000
2018	1496	1022	1007
2019	1511	1032	1017
2020	1526	1042	1027
2021	1539	1050	1035
2022	1558	1063	1048

4.7 Energy Efficiency Benefits

The new 230 kV circuit significantly increases the transmission capacity east of Bay d'Espoir to and allows for improved efficiency in the operation of generators at Holyrood. This results in reduced fuel consumption and, in turn, may reduce the potential for spill at hydroelectric facilities in a continued Isolated Operation generation expansion scenario. These values require extensive hydrological modeling to be quantified.

4.8 Losses During Construction

There are no anticipated losses during construction.

4.9 Status Quo

A solution involving the status quo would not be acceptable for generation expansion scenarios involving a Labrador Infeed or continued Isolated Operation.

In a generation expansion scenario involving the Labrador Infeed, the existing transmission system must be reinforced to maintain stability in the event of contingencies on the 230 kV system. Upgrades to the Bay d'Espoir East Transmission System are also required to ensure security of supply in the event of contingencies involving the loss of the Labrador Infeed via import from the Maritimes.

For a generation expansion scenario involving continued Isolated Operation, the limitations of the existing transmission system result in an inadequate transfer capacity for loads east of Bay d'Espoir. This is of particular concern as all proposed hydroelectric developments in this scenario are west of Bay d'Espoir.

4.10 Alternatives

Alternatives considered for this project include:

(1) Performing thermal upgrades on TL202, TL206 and TL203;
(2) Installing series compensation on TL202 and TL206;
(3) Constructing a new 230 kV transmission line from Bay d'Espoir to Western Avalon Terminal Station;
(4) Installing shunt capacitor banks;
(5) Performing thermal upgrades on TL202, TL206 and TL203, installing series compensation on TL202 and TL206, and installing shunt capacitor banks;
(6) Constructing a new 230 kV transmission line from Bay d'Espoir to Western Avalon Terminal Station and installing shunt capacitor banks;
(7) Adding a 315 kV transmission line ; or

(8) Adding a 315 kV transmission line and installing shunt capacitor banks.

Based upon the analysis in Section 4, a new 230 kV transmission line from Bay d'Espoir to Western Avalon Terminal Station (supplemented with reactive support in the form of shunt capacitor banks) is the preferred alternative for generation expansion scenarios involving both the Labrador Infeed and continued Isolated Operation.

5 CONCLUSION

It is recommended that a new 230 kV transmission line be constructed from Bay d'Espoir to Western Avalon Terminal Station. This upgrade is required to ensure the security of supply for loads east of Bay d'Espoir in generation expansion scenarios involving both a Labrador Infeed and a continued Isolated Operation. Budget Estimate

Table 8 - Budget Estimate

Project Cost: *($ x1,000)*	**2012**	**2013**	**2014**	**2015**	**2016**	**TOTAL**
Material Supply	0.0	14,288.8	13,645.0	18,465.5	1,677.5	48,076.8
Labour	2,042.0	2,330.0	2,288.0	2,502.0	2,973.1	12,135.1
Consultant	242.6	247.8	0.0	0.0	0.0	490.4
Contract Work	0.0	10,409.0	22,615.6	24,700.0	21,674.5	79,399.1
Other Direct Costs	165.1	181.2	205.0	273.0	340.1	1,164.4
Interest and Escalation	182.2	2,738.6	7,771.4	17,258.4	26,033.4	53,984.0
Contingency	0.0	0.0	0.0	0.0	14,126.5	14,126.5
	2,631.9	**30,195.4**	**46,525.0**	**63,198.9**	**66,825.1**	**209,376.3**

5.2 Project Schedule

Table 9 - Project Schedule: Year 1 - 2012

Activity		Start Date	End Date
Insulator Testing	• Perform Testing of NEMA insulators	Apr. 2012	Aug. 2012
Planning	• Determine Outage Schedule (as Required) • Survey TL Corridor and Terminal Stations	Jan. 2012 Jun. 2012	Mar. 2012 Aug. 2012
Design	• Preliminary Design, Structure Layouts	Apr. 2012	Aug. 2012
Procurement	• Tendering and Award	Apr. 2012	Nov. 2012
Construction	• Environmental Assessment and Draft Results	Jun. 2012	Aug. 2012
Commissioning	• Environmental Assessment Final Report	Nov. 2012	Nov. 2012
Closeout	• Update Design Data	Dec. 2012	Dec. 2012

Table 9 (Continued) - Project Schedule: Year 2 - 2013

Activity		Start Date	End Date
Planning	• Determine Outage Schedule as Required	Jan. 2013	Mar. 2013
Design	• Electrical/Civil/T&D Design for BDE TS	Feb. 2013	Jul. 2013
Procurement	• Tender and Award	Feb. 2013	Oct. 2013
	• Electrical Equipment Delivery	Mar. 2013	Dec. 2013
Construction	• Civil Earthworks	Apr. 2013	Oct. 2013
	• Transmission Line Construction	June 2013	Dec. 2013
Commissioning	• Review Civil/Transmission Earthworks	Nov. 2013	Nov. 2013
Closeout	• Update Design Data	Dec. 2013	Dec. 2013

Table 9 (Continued) - Project Schedule: Year 3 - 2014

Activity		Start Date	End Date
Planning	• Determine Outage Schedule as Required	Jan. 2014	Mar. 2014
Design	• Electrical Design	Feb. 2014	Jun. 2014
Procurement	• Electrical Equipment Delivery	Jan. 2014	Dec. 2014
	• Structure Steel Delivery	Jan. 2014	Apr. 2014
	• Electrical Construction Tender and Award	Apr. 2014	Sep. 2014
Construction	• Electrical Construction	Apr. 2014	Oct. 2014
	• Civil Transmission Line Construction	Apr. 2014	Nov. 2014
Commissioning	• Review Civil/Transmission Earthworks • Electrical Equipment	Nov. 2014	Nov. 2014
Closeout	• Update Design Data and Documents	Dec. 2014	Dec. 2014

Table 9 (Continued) - Project Schedule: Year 4 - 2015

Activity		Start Date	End Date
Planning	• Determine Outage Schedule as Required	Jan. 2015	Mar. 2015
Design	• Design Modifications	Apr. 2015	Nov. 2015
Procurement	• Electrical Equipment Delivery	Jan. 2015	Sep. 2015
Construction	• Electrical Construction	Apr. 2015	Oct. 2015
	• Transmission Line Construction	Apr. 2015	Nov. 2015
Commissioning	• Review TL Construction • Electrical Equipment	Nov. 2015	Nov. 2015
Closeout	• Update Design Data and Documents	Dec. 2015	Dec. 2015

Table 9 (Continued): Project Schedule: Year 5 - 2016

Activity		Start Date	End Date
Planning	• Determine Outage Schedule as Required	Jan. 2016	Mar. 2016
Design	• Design Modifications	Apr. 2016	Nov. 2016
Procurement	• P&C/Telecontrol Equipment	Jan. 2016	Mar. 2016
Construction	• Transmission Line Completion • P&C/Telecontrol Installation	Apr. 2016 Apr. 2016	Sept. 2016 Oct. 2016
Commissioning	• System Commissioning	Nov. 2016	Nov. 2016
Closeout	• Update Design Data and Documents	Dec. 2016	Dec. 2016