British Columbia Transmission CORPORATION™

Reinforcement Alternatives for the Interior to Lower Mainland Transmission Grid

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Transmission System Planning
British Columbia Transmission Corporation

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LIST OF ABBREVIATIONS

Abbreviation	Definition
AMC	American Creek Capacitor Station
ATC	Available Transfer Capability
CE	Canadian Entitlement
CHP	Chapmans Capacitor Station
CKY	Cheekye Substation
CPCN	Certificate of Public Convenience and Necessity
CRP	Contingency Resource Plan
DSM	Demand Side Management
EENS	Expected Energy Not Served
GUI	Guichon Capacitor Station
HVDC	High Voltage Direct Current
IDC	Interest During Construction
IEP	Integrated Electricity Plan
ILM	Interior to Lower Mainland
ING	Ingledow Substation
KLY	Kelly Lake Substation
LM	Lower Mainland
LTAP	Long Term Acquisition Plan
MDN	Meridian Substation
MSC	Mechanically Switched Capacitor
NIC	Nicola Substation
NITS	Network Integration Transmission Service
OH	Overhead
PV	Present Value
ROW	Right Of Way
RMR	Reliability Must Run
TRM	Transmission Reliability Margin
TTC	Total Transfer Capability
UEC	Upgrade Existing Circuits
VI	Vancouver Island

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EXECUTIVE SUMMARY

This report compares the reinforcement[1] alternatives considered for meeting the need for increased transfer capability of the Interior to Lower Mainland (ILM) transmission grid. Alternatives were screened using a number of attributes to narrow the alternatives requiring in depth comparison. In depth study was made of

(a) A set of upgrades for enhancing the thermal capacity of the existing lines of ILM transmission grid (the UEC alternative); and

(b) A new series compensated 500 kV AC transmission line between Nicola (NIC) and Meridian (MDN) substations (the 5L83 alternative).

The report shows that, from a system planning perspective, the 5L83 alternative is the preferred alternative.

Bulk electrical power from remote generation resources in the Interior is transferred to the Lower Mainland (LM) through a network of transmission lines known as the ILM grid. Most of the transferred power serves the LM load and BC Hydro’s firm export commitments on the western inter-tie to the US and the remaining power flows to Vancouver Island (VI). The balance of LM and VI load is supplied by local generation.

With growing load in the LM and on VI, limited dependable capacity of local generation resources, and expansion of Interior generation resources, the existing[2] Available Transfer Capability (ATC) of the ILM grid is forecast to become negative. A negative ATC would cause thermal and/or voltage stability limits on the ILM grid to be exceeded. Without removing the ILM limitations, reliable transfer of maximum or dependable capacity of the Interior generation resources would be compromised.

To improve the thermal and voltage stability limits, the ILM grid has to be reinforced and incremental Total Transfer Capability (TTC) has to be provided. This report reviews and compares the alternatives for increasing the TTC of the ILM grid.

[1] In the context of this report, “reinforcement” refers to a range of upgrades to the existing transmission system, including new transmission lines and rights of way.[1]
[2] In this report, existing refers to calendar year 2007

Thermal and voltage stability constraints of the ILM transmission grid can be fully or partially removed by one of the following three categories of alternatives: adding more Coastal Generation / additional Demand Side Management (DSM), upgrading the existing circuits, or building a new transmission line.

The ILM Alternatives

(a) Coastal Generation and/or additional DSM

Deferring the need for ILM reinforcement by designating high levels of Reliability Must Run (RMR) generation in the coastal regions of the LM and VI and by limiting the dispatch of Interior generation during heavy load hours, and/or by increasing energy conservation through greater use of DSM measures.

(b) Upgrade-Existing-Circuits (UEC)

Increasing the thermal rating of the existing transmission network through a combination of upgrading series capacitor banks, replacing circuit breakers, and increasing conductor ratings.

(c) New Line – 5L46

Construction of a new 500 kV series compensated circuit (5L46) between Kelly Lake (KLY) and Cheekye (CKY) substations through the Pemberton Valley and Whistler corridor. This line would be approximately 203 km long and for most of the route, would parallel the existing 5L42 circuit but some new ROW would be required.

(d) New Line – 5L83

Construction of a new series compensated 500 kV circuit (5L83) between NIC and MDN generally paralleling existing lines. 5L83 would be approximately 244 km long and existing rights-of-way (ROW) would be available for the majority of the route

(e) New Line – NIC to ING

Construction of a new 500 kV series compensated line directly between NIC and Ingledow (ING) substations directly or by extending 5L83 from MDN to ING. This circuit would require acquisition of new ROW in parts of the Fraser Valley.

(f) HVDC

Applying HVDC technology to transfer the Interior power from NIC to MDN either by a new 500 kV HVDC bi-pole or by converting the existing 5L81 and/or 5L82 AC circuits to HVDC.

Screening of Alternatives

Initially, all identified alternatives were compared using a number of attributes, including increase in TTC and cost, to screen the more likely ILM solutions. The conclusions of the screening analysis are captured in this report and indicate that 5L46, NIC to ING, HVDC, and Coastal Generation/DSM are not the preferred alternatives for reinforcing the ILM grid. Initial comparison of 5L83 and UEC showed that both of these alternatives have similar continuous and one hour thermal overload transfer capabilities. These two alternatives were further analyzed in terms of their present value (PV), reactive power requirements, transmission losses, double outage performance, and reliability.

Comparison of 5L83 and UEC Alternatives

(a) The 5L83 and UEC alternatives could increase the continuous thermal capability of the existing ILM grid from 5000 MW to 6750 MW and 6570 MW respectively. However, the ILM grid would then be limited by voltage stability to 6550 MW for 5L83 and to 5,800 MW for the UEC and would require additional reactive power to support heavy ILM flows. With 470 MVAr reactive power additions, the voltage stability limit of the ILM grid would increase from 6550 MW to 7120 MW for 5L83 and from 5800 MW to 6355 MW for UEC.

(b) Compared to the UEC alternative, 5L83 would save 307 GWh/yr in transmission energy losses.

(c) For energy valued at $74.0/MWh, the PV of costs for 5L83 would be $373.4 M less than the UEC alternative. For long-term planning of the ILM grid, if 5L83 is built first and followed by a limited number of the UEC upgrades after six years, there would be $150 M savings in the PV of costs. The difference in the PV of costs is mainly attributed to the lower transmission energy losses associated with 5L83.

(d) Double outage generation shedding requirements for 5L83 would be between 669 MW and 1255 MW less than similar requirements for the UEC alternative.

(e) Double outage load shedding requirements for 5L83 would be between 517 MW and 1060 MW less than similar requirements for the UEC alternative.

(f) Compared to the UEC alternative, 5L83 would improve the Expected Energy Not Served (EENS) reliability index by approximately 12 MWh/yr. The reliability improvement over the UEC alternative is not considered significant.

Conclusion

It is the conclusion of this report that building a new transmission line, 5L83, is the preferred alternative for increasing the TTC of the ILM grid.

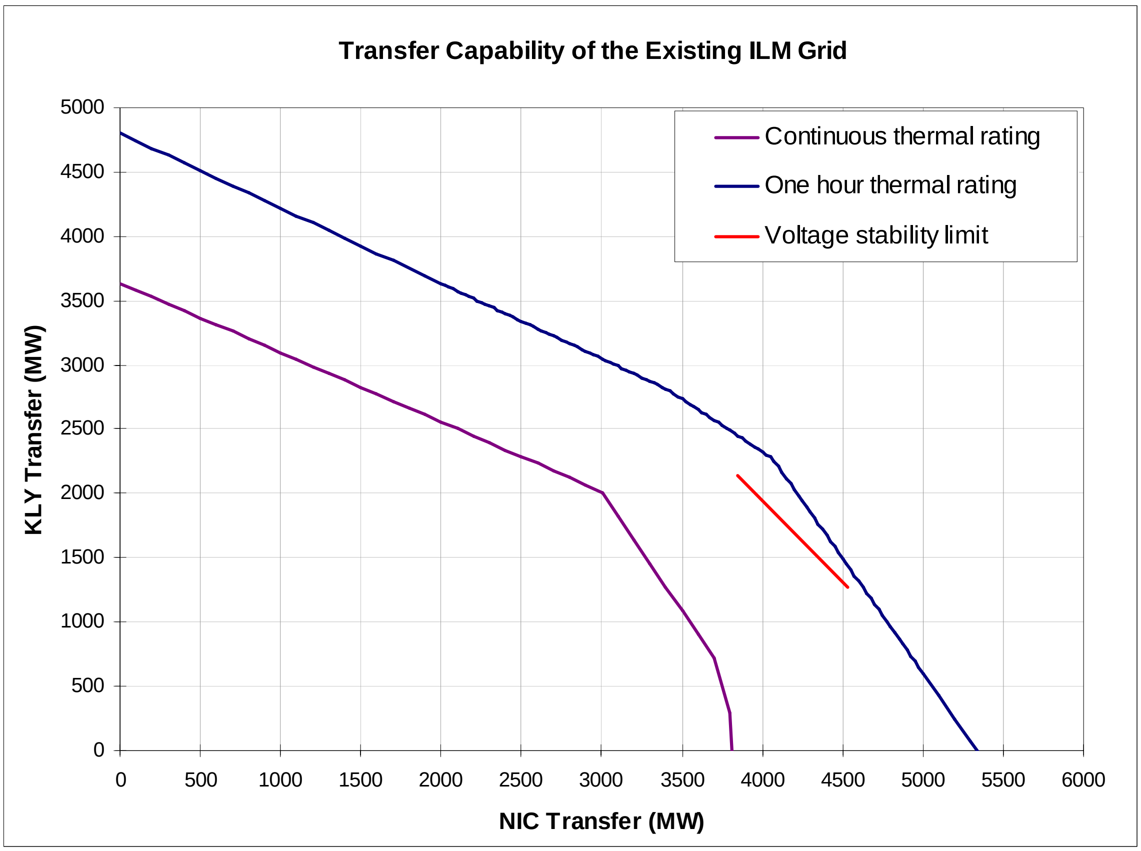
1.0 INTRODUCTION

The need for reinforcing the ILM transmission grid is assessed in System Planning Report SPA2007-25. This Reinforcement Alternatives report (SPA2007-28) reviews the results of the alternatives identification and assessment process conducted by BCTC to arrive at a preferred alternative for the ILM Project.

1.1 Relying on the Existing ILM Grid (Do-Nothing)

The ILM transmission grid is constrained by its thermal and voltage stability ratings. These limits are illustrated in Figure 1-1.

Figure 1-1. Limits of the Existing ILM Grid



The existing ILM transmission grid has a continuous thermal rating of 4550 MW to 5011 MW depending on the amount of generation transferred from NIC versus generation transferred from KLY. The one-hour thermal overload rating of the existing system is approximately 6300 MW. The existing system has a voltage stability limit of approximately 5800 MW. Operation of the ILM grid must consider the constraints of the system identified by these limits.

In SPA2007-25, it is shown that the existing demand on the ILM grid already exceeds its continuous thermal rating. Currently, the ILM continuous thermal limit violation is addressed by operating the pre-outage grid up to the voltage stability limit of 5800 MW. In the event of a contingency, the system can sustain transfers up to 5800 MW (the voltage stability limit) provided the contingency event does not exceed one hour. If an ILM outage exceeding one hour occurs, then local generation and available imports, such as the Canadian Entitlement (CE), would be re-dispatched to reduce the required transfers on the ILM grid down to the continuous thermal rating of approximately 5000 MW. From a planning perspective, BCTC is not in a position to rely on the one hour thermal rating unless it knows that there is a firm resource available that could be re-dispatched to reduce the transfers on the ILM grid to its continuous rating.

In many of the planning scenarios described in SPA2007-25, the CE is not available for transmission planning purposes after 2014. As a result, in these scenarios, the current mode of operation could not continue and the existing ILM grid would then be limited to operation at or below its continuous thermal rating.

1.2 Definition of the ILM Alternatives

BCTC examined a number of alternatives as candidates for a preferred solution to meet the need for incremental ILM transfer capability. The alternatives identified are briefly described below.[3]

1.2.1 Coastal Generation and/or Additional DSM

The ILM reinforcement can be deferred by designating high levels of Reliability Must Run (RMR) generation in the coastal regions of the Lower Mainland (LM) and Vancouver Island (VI) and by limiting the dispatch of Interior generation during heavy load hours. Recognizing that the Network Load in BC is served by both Interior and

[3] For each alternative, the best estimate of the design parameters is provided to allow screening of alternatives. Once the preferred alternative is approved, the exact circuit parameters would be developed in a system application document

Coastal resources, additional dispatch of Coastal Generation would reduce the amount of Interior dispatch. Consequently, the flow on the ILM grid would be reduced.

This alternative assumes that future Coastal Generation would be adequate to limit the peak power flows on the ILM grid to its existing thermal and voltage stability limits. Coastal Generation could include new generation projects or continued generation from Burrard Generating Station (Burrard) beyond 2014. Continued availability of the CE for use as a transmission planning resource, designation of firm energy imports on existing facilities or future facilities such as the proposed Juan de Fuca project, or additional DSM measures in the LM and VI over and above those levels identified in existing resource plans, could also act as alternatives similar to Coastal Generation.

1.2.2 Upgrade-Existing-Circuits (UEC)

The following group of projects is referred to as the UEC alternative:

(a) Upgrade of Chapmans (CHP) series capacitor banks to 2.73 kA (at 1.0 PU Voltage)

(b) Upgrade of CRK series capacitor banks to 2.73 kA (at 1.0 PU Voltage)

(c) Upgrade of American Creek (AMC) series capacitor banks on 5L81 and 5L82 to 3.0 kA (at 1.0 PU Voltage)

(d) Upgrade of Guichon (GUI) series capacitor banks to 2.73 kA (at 1.0 PU Voltage)

(e) Upgrade summer rating of 5L41 to 3.0 kA

(f) Upgrade summer rating of 5L42 to 3.0 kA

(g) Upgrade summer rating of 5L44 to 3.0 kA

(h) Upgrade summer rating of 2L1/2L5 to 0.98 kA

(i) Replace ING circuit breakers 5CB7, 5CB8, and 5CB11 with 3.0 kA circuit breakers

(j) Replace ING circuit breakers 5CB9 and 5CB10 with 4.0 kA circuit breakers

(k) Replace NIC circuit breakers 5CB12, 5CB18, 5CB22, and 5CB28 with 4.0 kA circuit breakers

(l) Replace MDN circuit breakers 5CB7 and 5CB8 with 4.0 kA circuit breakers

The approximate continuous thermal capacity of the UEC-reinforced ILM grid would increase from the existing 5000 MW to 6570 MW (at 2000 MW KLY transfer). With the addition of 470 MVAr of reactive power,[4] the voltage stability limit of the UEC-reinforced ILM grid would increase from 5800 MW to 6355 MW. Therefore, the TTC of the UEC-reinforced ILM grid would become 6355 MW.

1.2.3 New Line – 5L46

Construction of a new 500 kV series compensated line between KLY and CKY substations through the Pemberton Valley and Whistler corridor. 5L46 would be approximately 55% series compensated. The circuit would have line terminations at KLY and CKY, one 122.5 MVAr line reactor at KLY, one 122.5 MVAr switchable line reactor at CKY, and a series capacitor station, preferably at Creekside (CRK) or near the middle of the line. The approximate length of the circuit would be 203 km. Total impedance of the series compensated 5L46 circuit would be similar to the compensated impedance of the existing KLY-CKY line 5L42 to allow similar flows on both lines. At flow patterns that correspond to 2000 MW transfer from KLY, the 5L46 alternative would increase the continuous thermal capacity of the ILM grid from the existing 5000 MW to approximately 5200 MW. The 5L46 alternative would increase voltage stability limit of the ILM grid from 5800 MW to approximately 6384 MW. Addition of 470 MVAr of reactive power support would further increase the voltage stability limit of the 5L46-reinforced network from 6384 MW to 6748 MW. Therefore, the TTC of the 5L46-reinforced ILM grid would be limited by its thermal capacity of 5200 MW. The expected continuous rating of the transmission circuit would be 3.0 kAmp.

1.2.4 New Line – 5L83

5L83 would be a new 500 kV transmission circuit between NIC and MDN, approximately 50% series compensated, one 122.5 MVAr line reactor at NIC, and a series capacitor station preferably near the middle of the line. The approximate length of the circuit would be 244 km.

[4] One 250 MVAr mechanically switchable capacitor (MSC) at NIC 500 kV and two 110 MVAr MSCs at MDN 230 kV.

For the majority of the route, 5L83 would parallel existing 5L82 using existing ROW. Total impedance of the series compensated 5L83 circuit would be similar to the compensated impedance of the existing NIC-MDN line 5L82 to allow similar flows on both lines. At flow patterns that correspond to 2000 MW transfer from KLY, the 5L83 alternative would increase the continuous thermal capacity of the ILM grid from the existing 5000 MW to approximately 6750 MW. The 5L83 alternative would increase voltage stability limit of the ILM grid from 5800 MW to approximately 6550 MW. Addition of 470 MVAr of reactive power support would further increase the voltage stability limit of the reinforced network to 7120 MW. Therefore the TTC of the 5L83-reinforced ILM grid would be limited by its continuous thermal capacity of 6750 MW. The expected continuous rating of the transmission circuit would be 3.0 kAmp.

1.2.5 New Line – NIC to ING

BCTC considered two corridor options for termination of a new line at ING:

(a) A new 500 kV line that followed a corridor directly between NIC and ING and

(b) Building 5L83 between NIC and MDN and a new line between MDN and ING.

A number of route alignments were examined under the two corridor options. The least expensive alignment between NIC and ING would consist of 5L83 plus a new 500 kV line double-circuited with 5L44 from MDN to Port Mann Bridge and another 500 kV line double-circuited with 2L22 and 2L27 to ING along the existing ROW. These options would have similar thermal and voltage stability ratings as the 5L83 alternative discussed above.

1.2.6 HVDC

This alternative would use HVDC technology to transfer Interior power from NIC to MDN either by a new conventional +/- 500 kV HVDC bi-pole or by converting the existing 5L81 and/or 5L82 AC circuits to HVDC. An HVDC option would be designed to have similar incremental one hour thermal overload and continuous thermal capabilities as 5L83. Conversion of the existing AC circuits to DC would include both bi-pole and tri-pole technologies. To minimize the cost of tri-pole conversion, converting 5L82 to tri-pole HVDC would be done in 2014 followed by conversion of 5L81 around 2020.

2.0 SCREENING OF THE ILM ALTERNATIVES

A screening analysis of the identified alternatives was conducted to reduce the range of potentially feasible alternatives to a manageable list for further comparison by identifying those alternatives that are clearly preferred to other potential alternatives. This level of analysis does not require the development of each alternative in terms of performance assessment or cost estimation to the same level of precision ultimately required of a preferred alternative submitted in an application for a Certificate of Public Convenience and Necessity (CPCN). In some instances, an alternative will be found to be sufficiently inadequate in comparison to the remaining alternatives that further detailed analysis on the inadequate alternative is not required. The screening analysis then continues through an iterative process with the remaining alternatives until a reduced set for detailed analysis has been selected.

BCTC considered the following attributes during the screening analysis:

(a) TTC as limited by continuous thermal limits and voltage stability limits

(b) Reliability as indicated by Expected Energy Not Served (EENS)

(c) Cost

(d) Losses, and

(e) Double outage requirements.

2.1 Coastal Generation and/or Additional DSM

Coastal Generation is defined as generation from plants in the LM and VI. Increases in either Coastal Generation or DSM would reduce the necessary transfer, and therefore need for increased TTC, on the ILM grid. Designation of additional firm import energy on the proposed Juan de Fuca project or continued use of the CE for re-dispatch as a planning resource, would generally have a similar impact as more Coastal Generation.

BC Hydro included forecasts of Coastal Generation and DSM measures in its 2004 NITS Application, 2006 Integrated Electricity Plan (IEP), and 2006 Long Term Acquisition Plan (LTAP) resource portfolios. During BC Hydro’s IEP/LTAP

Proceeding, BCTC also assessed additional portfolios with variations of availability of Burrard generation and the CE for re-dispatch as a planning resource. The above-mentioned portfolios contain varying levels of Coastal Generation and DSM. In support of BC Hydro's 2006 IEP, BCTC analyzed the transmission implications of seventeen resource portfolios. The need for increased TTC of the ILM grid was confirmed in sixteen of these portfolios. In terms of in-service date, thirteen of the reviewed portfolios had a 2013 in-service date, one 2014, one 2016, and one portfolio had a 2020 in-service date. The only load/resource portfolio that did not require reinforcement of the ILM transmission grid was based on the addition of approximately 2300 MW new generation near the load.

During BC Hydro's 2006 IEP/LTAP proceeding, BCTC conducted an analysis of the ILM requirements for the Amended Long Term Acquisition Plan (LTAP), Contingency Resource Plan (CRP)1, and CRP2 portfolios. These analyses were based on the December 2006 load forecast. BCTC also examined the impact of re-powering Burrard, applying the CE as a network resource, and dispatching maximum or dependable capacity of Interior generation resources on the timing of ILM reinforcement. The need for reinforcing the ILM grid was confirmed in all eighteen of the examined scenarios. In terms of in-service date, ten of the reviewed portfolios had a 2014 in-service date, two 2017, two 2018, one 2019, one 2020, and two portfolio had a 2023 in-service date.

While increases in Coastal Generation or DSM could defer the need for increasing the TTC of the ILM grid, BCTC needs to plan the transmission system to meet those scenarios that require additional ILM transfer capability as early as 2014 as well as dealing with scenarios where the need for incremental capacity might arise later. Should greater Coastal Generation and/or DSM materialize than the amounts forecast in the above-identified portfolios, it would tend to defer the need for incremental ILM transfer capability. In that event, BCTC would be in a position to consider its impact on the timing of the ILM Project. However, because BCTC must also be able to deal with scenarios that require earlier in-service dates, additional Coastal Generation or DSM is not considered a viable alternative from a planning perspective.

2.2 5L46

Performance of the 5L46 alternative was evaluated and compared to the existing system, 5L83, and UEC using their respective thermal and voltage stability nomograms. Figure 2-1 shows the peak hour N-1 thermal overload nomograms of the existing ILM grid, addition of 5L83, addition of UEC, and addition of 5L46. Figure 2-2 presents a similar set of nomograms for the continuous thermal ratings of the above ILM alternatives and Figure 2-3 represents the set of nomograms showing the alternatives' voltage stability performance.

Figure 2-1. Thermal Overload Limits of the ILM Alternatives

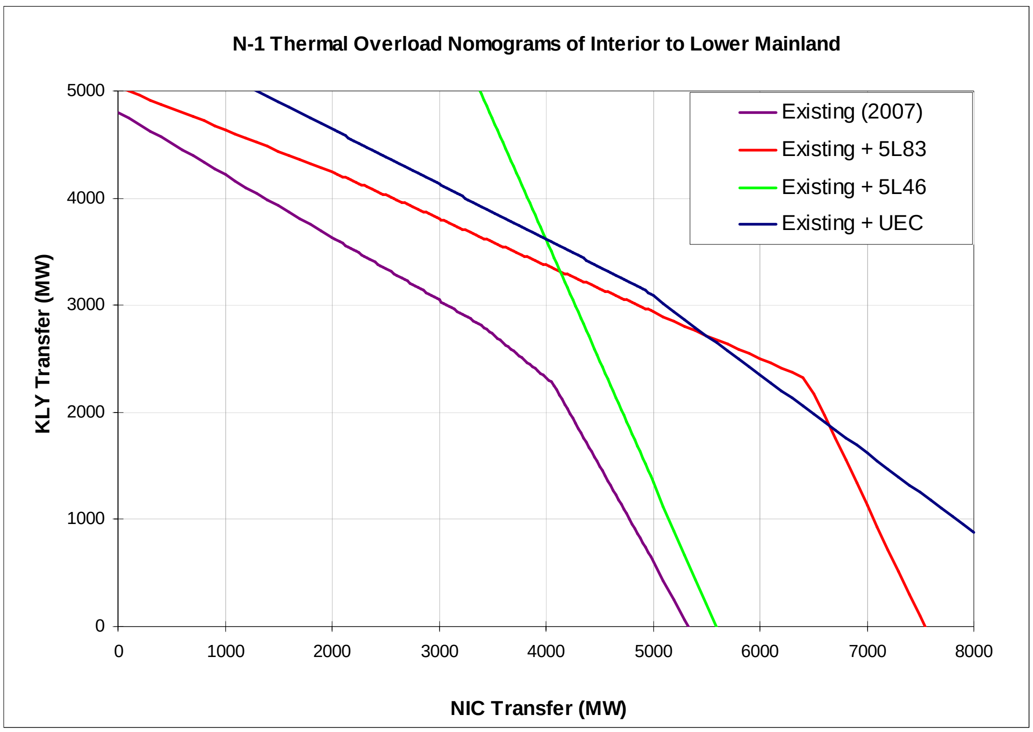


Figure 2-2. Continuous Thermal Limits of the ILM Alternatives

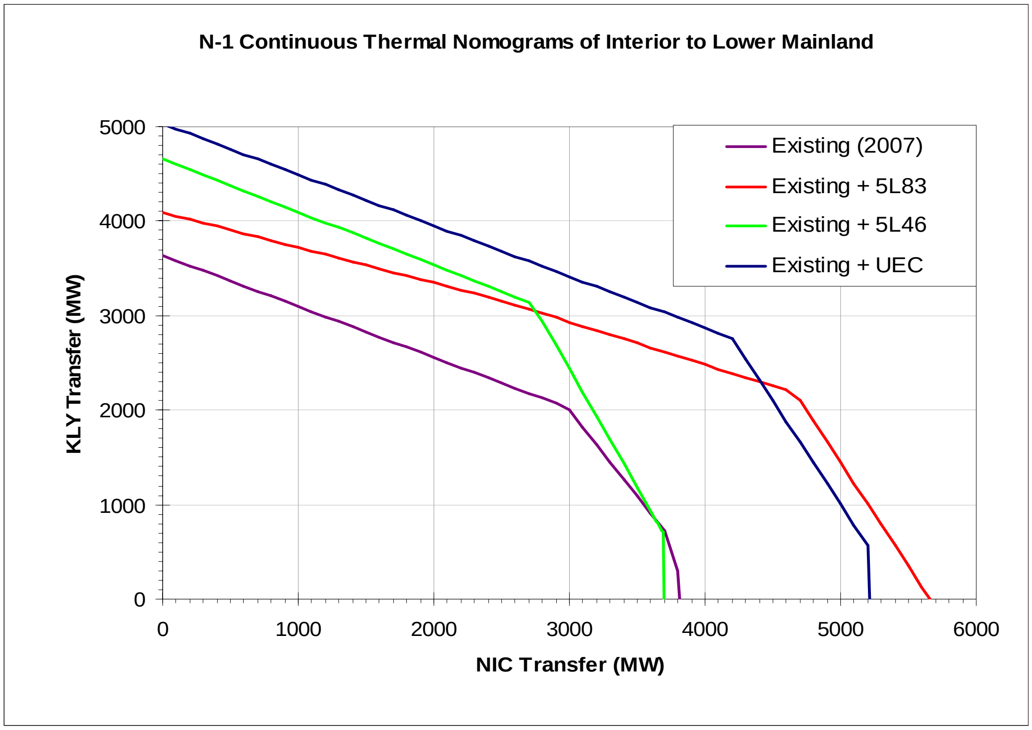
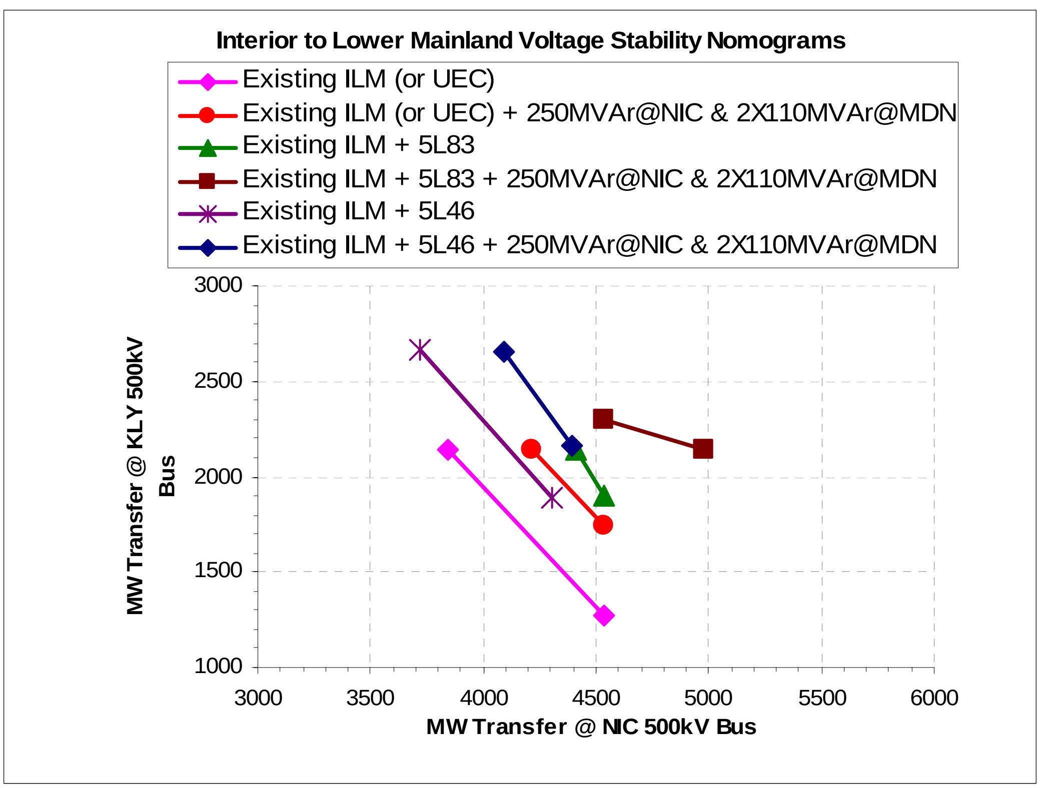


Figure 2-3. Voltage Stability Ratings of the ILM Alternatives



These nomograms illustrate that 5L83 and UEC alternatives provide higher incremental ILM thermal transfer capabilities from the NIC side. The 5L46 circuit enhances thermal transfer capabilities from the KLY side but has limited impact on the NIC side.

In BC Hydro’s Amended LTAP, CRP1, and CRP2, most of the future resources would be in the South Interior region. Transferring dependable capacity of these resources to the LM and VI would require improvements in the transfer capability of the ILM grid from the NIC side. Consequently, 5L83,and UEC would better match the LTAP, CRP1, and CRP2 requirements from a thermal perspective and 5L83 would be a better voltage stability match. In a longer planning horizon, it is likely that 5L46 will still be needed to address requirements for increased transfer capability from the NI, but that is not the present need.

5L46 would also not reduce system losses to the same extent as 5L83. Estimated annual losses, at 6750 MW ILM flow and 2000 MW flow from KLY, are forecast to be 1009 GWh for a 5L46-reinforced ILM grid as compared with 882 GWh with a 5L83-reinforced grid.

5L46 would likely require new ROW for some of its 203 km. 5L46 was also found to require more double outage generation shedding and load shedding than 5L83 or alternatives addressing ILM transfer capability from the NIC side.

2.3 New Line NIC to ING

NIC to ING is expected to have similar performance to 5L83 from a one-hour thermal, continuous thermal, and voltage stability perspective. Therefore, it would address the need for incremental TTC of the ILM grid. NIC to ING would also be expected to have similar loss performance to 5L83 and, as discussed below, would be superior to UEC in this respect.

Terminating the new line at ING would increase the firm transfer capability to ING relative to 5L83 (terminating at MDN). This could facilitate additional electricity trade opportunities on the western inter-tie. However, the domestic load requirements and firm export commitments would be met by the increased transfer capability provided by 5L83.

The least expensive transmission option for transferring power from NIC to ING would be building a new 500 kV circuit between NIC and MDN substations and a new 19 km 500 kV double circuit with 5L44 from MDN to Port Mann Bridge and another 500 kV double circuit with 2L22 and 2L27 to ING along the existing ROW. Therefore, since BCTC could meet the need for increased transfer capability on the ILM grid with 5L83 alone, and the most cost effective way of increasing transfer capability to ING is with 5L83 and a new circuit from MDN to ING, the potential trade opportunity identified above would not be lost by building 5L83. The MDN to ING circuit may be a candidate for consideration as a separate project justified by trade benefits and brought forward by BCTC pursuant to Article 4 of Special Direction No. 9. Detailed analysis of trade benefits is not considered in this report.

In conclusion, a direct NIC to ING line was not studied further because BCTC could meet the need for increased transfer capability on the ILM grid with 5L83 alone and the future potential trade opportunity identified above would not be lost by building 5L83.

2.4 HVDC

In 2007, BCTC hired an external consulting firm (DC Interconnect Inc. - DCI) to investigate the feasibility and cost of possible HVDC alternatives that would provide similar incremental thermal capabilities as 5L83. HVDC alternatives reviewed included a new HVDC circuit from NIC to MDN and conversion of existing AC lines to HVDC. The analysis identified that HVDC solutions could be designed that would be similar to the expected thermal overload, continuous thermal and voltage stability ratings of the 5L83-reinforced ILM grid.

DCI reviewed the HVDC converter costs, reactive support requirements, and loss performance of the HVDC solutions and compared these to the expected performance of 5L83.

In June 2007 the DCI report concluded that the cost of HVDC converter stations, not including overhead and interest during construction, would be as high as $378M ($2007).

A typical HVDC bi-pole transmission line requires less right of way, smaller towers, and fewer conductors than an AC transmission line. The savings in transmission line costs are estimated to be 20-30 percent[5]. The cost of the transmission line component of 5L83 was estimated in April 2007 at $253.5 M (direct with no contingency, inflation, overhead, or interest during construction[6]). Therefore, an HVDC bi-pole circuit would cost between $177 M and $203 M in transmission line costs.

Combined with the HVDC converter station costs at each end of the circuit, the total transmission cost of an HVDC solution would be between $555 M and $581 M. This does not include contingency, inflation, OH, and IDC which would be assumed to be the same as for an AC transmission line. In general, HVDC transmission becomes cost competitive with AC for transmission lines longer than 500km. Beyond this distance, the savings in transmission losses and line costs offset the additional HVDC converter station cost.

The cost comparisons made above use a cost estimate prepared in April 2007 so that it was consistent with the time when the converter cost estimate was made.

In conclusion, HVDC was not studied further because it would be expected to be substantially more expensive than AC in terms of capital costs.

3.0 DETAILED COMPARISON OF 5L83 TO UEC

Having concluded the initial screening analysis, BCTC subjected the surviving alternatives 5L83 and UEC to a more detailed review. In this section, determining factors associated with the two alternatives are examined using the following seven planning indicators:

(a) Thermal Overload Capacity

(b) Continuous Thermal Capacity

(c) Voltage Stability

(d) Network Losses

(e) PV of Costs

[5] ABB Paper – The ABC's of HVDC Transmission Technologies
http://www.abb.com/cawp/gad02181/c1256d71001e0037c12568940025fdbe.aspx
[6] Overhead: OH, Interest During Construction: IDC

(f) Double Outage Limitations

(g) EENS Reliability Performance

3.1 Thermal Overload Capacities

Use of one hour thermal overload ratings as an operating constraint allows the system to be operated above the continuous thermal rating for one hour. This hour allows system operators to adjust the post-outage network flows to stay within the continuous and voltage stability ratings of the network. BCTC has in the past been able to plan the system with the one-hour thermal overload rating as the governing constraint because local generation and energy imports were considered available for re-dispatch in the event of a contingency. Local reactive reinforcements were forecast when necessary to overcome any voltage stability limits.

The difference between the thermal overload capacities of 5L83 and UEC alternatives is not a single number. Instead, this difference is defined by the one-hour N-1 nomograms of the two alternatives. The addition of 5L83 would change the shape of the existing ILM nomogram and would extend it to new boundaries. Reinforcing the existing system with the UEC alternative would also change the boundaries of the existing ILM nomogram.

Figure 2-1 shows the peak hour thermal overload N-1 nomograms of the ILM transmission grid for the existing system and alternatives including 5L83 and UEC. On average, for most peak hour points, the difference between the thermal overload capacities of the two reinforcement alternatives is not significant. This does not mean that full amount of thermal overload capacity can be used. Both 5L83 and UEC would require significant reactive power support to allow their thermal overload capacity to be used. The reactive power requirements are addressed in Section 3.3.

3.2 Continuous Thermal Capacities

As noted above, the availability of the CE and Coastal Generation for re-dispatch has previously allowed BCTC to plan the ILM grid using the one-hour thermal overload rating as the limiting constraint. For the resource scenarios which require the ILM Project as early as 2014, the CE is not available beyond 2014. In these scenarios, the continuous thermal rating becomes the governing thermal constraint. As a result, BCTC must make sure that the ILM transmission grid is adequately reinforced such that, following a long-term outage of a transmission circuit, the remaining network would stay within its continuous thermal and voltage stability limits.

The continuous thermal rating of the existing ILM grid is not a single number. Figure 2-2 ndicates that the continuous thermal rating of the existing ILM grid can vary between 4550 MW[7] and 5011 MW[8] . The addition of 5L83 or UEC would improve the continuous thermal limits of the ILM grid to its new boundaries also shown in Figure 2-2.

Comparing continuous thermal nomograms of the existing and reinforced ILM grid shows that, for KLY transfers between 1000 MW and 2000 MW, the continuous thermal capabilities of the ILM reinforcement alternatives vary between 6000 MW and 6570 MW for UEC and between 6220 MW and 6750 MW for 5L83. However, once 5L83 or UEC were completed the voltage stability rating for both alternatives would be lower than the continuous thermal rating. Absent additional reactive support, voltage stability would become the governing constraint.

3.3 Voltage Stability

The existing voltage stability limit of the ILM grid is approximately 5800 MW. Addition of 5L83 is expected to increase the voltage stability limit to approximately 6550 MW. The UEC alternative on the other hand is comprised of a series of thermal upgrades that would not change the existing voltage stability limit.

The voltage stability limits can be increased with reactive support. After adding one 250 MVAr/500 kV MSC at NIC and two 110 MVAr/230 kV MSCs at MDN, the 5L83-reinforced ILM grid would have a voltage stability limit of approximately 7120 MW. For the UEC alternative, addition of the above MSCs would increase the voltage stability limit to only 6355 MW. This would be a respective increment of 1320 MW and 555 MW for 5L83 and UEC alternatives. For either alternative, a higher level of reactive power reinforcement is not considered efficient.

[7] Corresponding to 3550 MW flow from NIC and 1000 MW flow from KLY
[8] Corresponding to 3011 MW flow from NIC and 2000 MW flow from KLY

3.4 Network Losses

The expected energy losses of the ILM transmission network, after commissioning of the grid with 5L83 or the UEC alternative, were calculated and compared. The ILM energy losses associated with UEC alternative were greater than energy losses for 5L83.

The difference between transmission losses of the ILM grid for 5L83 and UEC after 2014 are calculated and are based on the following assumptions:

(a) Load and Load Curve: In this analysis, the December 2006 load forecast was used to simulate the 2014/15 peak hour load. To represent the expected load and loss variations and to estimate the average energy losses in 2014/15, the recorded 2005/2006 load curve was applied.

(b) Generation and ILM Flow: To simulate the generation that would supply the peak hour load and transmission losses in 2014/15, generation up to the dependable capacity of the Amended LTAP resources were dispatched. The peak hour flow on the ILM transmission grid was restricted by the voltage stability limit of the UEC alternative with 470 MVAr of reactive reinforcement of 6355 MW.

(c) Loss Comparison: While the UEC alternative is not expected to improve the resistance of the existing ILM grid, the new transmission line 5L83 would reduce it by providing a parallel path to the existing ILM lines. Consequently, lower transmission energy losses were expected for cases with a new transmission line.

The loss analysis indicated that, when compared to the UEC alternative, 5L83 would reduce the average 2014/15 transmission energy losses by approximately 307 GWh. The impact of energy loss savings in the long-term planning of the ILM grid is discussed in Section 3.5.3.

3.5 PV of Costs

The estimated capital costs of both 5L83 and UEC alternatives are summarized in Table 3-1. Each cost item is in 2007 un-inflated Dollars and includes OH but not IDC. At the time of estimating, all cost estimates were considered accurate within -5/+30%.

Table 3-1. Estimated Capital Costs of 5L83 and UEC

Line	UEC Alternative Group of Projects	Cost ($M) Est. Apr. 07	5L83 Alternative Group of Projects	Cost ($M) Est. Apr. 07
1	UEC – Definition Phase	12.4		
2	UEC – Implementation Phase	3.4		
	<u>Series Capacitor Upgrades</u>			
3	CHP (5L41) upgraded to 2.73 kA	13.1	5L83 – Definition Phase	27.3
4	CRK (5L42) upgraded to 2.73 kA	12.9	5L83 – Implementation Phase	333.7
5	AMC (5L81) upgraded to 3.0 kA	14.1	5L83 – Series Compensation	31.6
6	AMC (5L82) upgraded to 3.0 kA	14.2	5L83 – MDN Termination	5.9
7	GUI (5L87) upgraded to 2.73 kA	7.0	5L83 – NIC Termination	8.0
	<u>Line Upgrades</u>		**Total Cost "5L83 Alternative"**	**$406.5 M**
8	2L1/2L5 upgraded to 0.98 kA Summer	2.3		
9	5L41 upgraded to 3.0 kA Summer	57.2		
10	5L42 upgraded to 3.0 kA Summer	16.3		
11	5L44 upgraded to 3.0 kA Summer	2.5		
	<u>500 kV Circuit Breaker Replacement</u>			
12	ING 2 x 3 kA 5CB7 and 5CB8 (5L40)	2.4		
13	ING 1 x 3 kA 5CB11 (5L44)	1.7		
14	ING 2 x 4 kA 5CCB9 and 5CB10 (5L81)	3.7		
15	NIC 2 x 4 kA 5CB18 and 5CB28 (5L81)	4.0		
16	NIC 2 x 4 kA 5CB12 and 5CB22 (5L82)	4.0		
17	MDN 2 x 4 kA 5CB7 and 5CB8 (5L82)	5.7		
19	**Total Cost "UEC Alternative"**	**$176.8 M**		

A simple comparison of the numbers shows that total cost of 5L83 would be $229.7 M more than total cost of UEC alternative. However, this figure is not reflective of factors such as savings in energy losses, operating and maintenance (O&M) expenses, reactive power requirements, and applicable taxes.

In this report the costs of the 5L83 and UEC alternatives are compared on a present value (PV) basis. The PV calculations are inclusive of capital costs, energy loss savings, O&M costs of transmission lines and substations, and grants in lieu of taxes. Although individual UEC projects can be delivered sooner than a new transmission circuit, in this cost analysis it is assumed that both alternatives would be completed in

October 2014. With this assumption, all fixed costs are placed in service in 2014 and are added to the PV of all recurring costs. Also in this PV analysis the capital cost of one 250 MVAr / 500 kV MSC at NIC and two 110 MVAr / 230 kV MSCs at MDN are added to both 5L83 and UEC alternatives.[9]

The economic comparison is done by modeling differences in operating costs, taxes and losses for the life of the alternatives being compared. It is assumed that the transfer on the ILM grid never exceeds the 6355 MW TTC of the UEC alternative. Also, it is assumed that future LM and VI load growth would be met by a combination of future increases in the Coastal Generation, DSM, and imports on the western inter-tie.

The following parameters are used in the PV comparison of 5L83 and UEC alternatives:

(a) All capital costs are in 2007 un-inflated Dollars

(b) The ISD of both 5L83 and Upgrade-Existing-Circuits upgrades: 2014

(c) Discount rate: 2.50 %

(d) Duration of the PV analysis: 50 years

(e) O&M annual rate for steel towers: 0.10%

(f) O&M annual rate for substations: 1.01 % [10]

(g) Annual taxes for 500 kV transmission lines: $4,056/km

(h) Annual tax rate on physical plant: 1.47 %

(i) Annual rate of increase in the price of energy: 0.00 %

(j) Value of energy [11]: $74.00/MWh

[9] The approximate $9 million costs of NIC and MDN MSCs are included in the BCTC's F2008 Transmission System Capital Plan
[10] O&M rates do not apply to OH and IDC
[11] BC Hydro F2006 Call Weighted Average Levelized Plant Gate Price. Source: BC Hydro response to BCUC IR 4.451.2, dated September 8, 2006, 2006 BC Hydro IEP / LTAP proceeding

Results of the cost comparison and the cost comparison tool, which was used for developing these results, are shown in Appendix A. A summary of the results is shown in Table 3-2.

Table 3-2. PV of Total Costs

	ILM Alternative	PV of Costs ($M)
1	UEC	251.5
2	5L83	- 121.9
3	Difference: UEC – 5L83	373.4

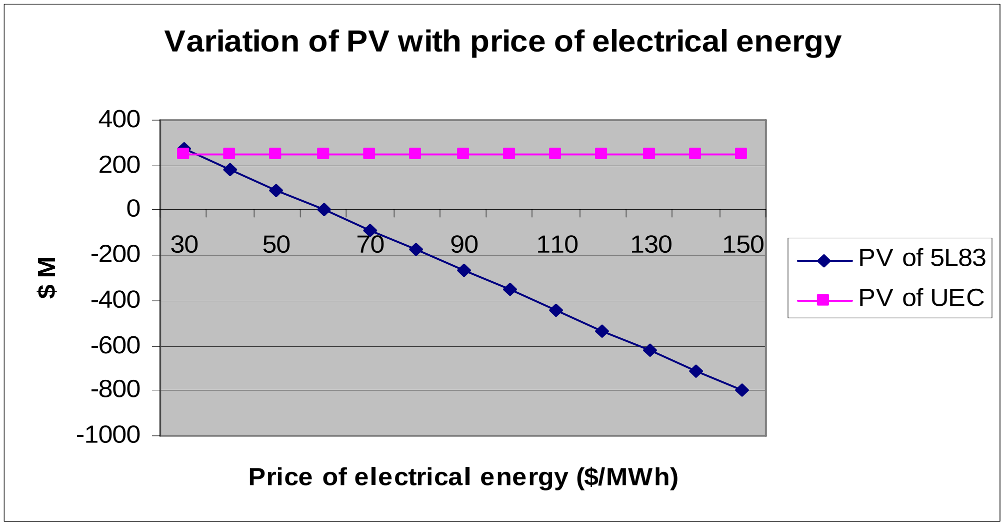
The table indicates that for energy losses valued at $74/MWh, the PV of 5L83 costs would be $373.4 M less than the PV of UEC costs. The lower PV of costs makes 5L83 fiscally more attractive than the UEC alternative notwithstanding the UEC’s lower capital costs.

3.5.1 Variation of PV With Price of Energy

In Section 3.5, the savings in transmission energy losses were a significant factor in making 5L83 less costly than the UEC alternative. The value of energy loss savings is directly proportional to the traded price of electricity. In the previous section, the traded price of electricity is assumed to be fixed at $74.0/MWh.

The actual price of energy is set by market forces and can be different from the assumed value. This section reviews the difference in the PV of 5L83 and UEC alternative for energy prices ranging from $30/MWh to $150/MWh. Results of this sensitivity analysis are shown in Figure 3-1.

Figure 3-1. Sensitivity Analysis Based on the Price of Electrical Energy



Review of Figure 3-1 leads to the following conclusions:

(a) If electricity were traded at $32/MWh, then the PV of both 5L83 and UEC alternatives would become similar.

(b) Higher electricity prices would improve the attractiveness of 5L83 over UEC from a financial perspective.

The savings in transmission energy losses are expected to start in 2014 after reinforcing of the ILM grid. Up to this point, it is assumed that the price of energy and the associated savings remain constant after 2014. However, the actual market price of energy has not stayed constant over the last few years and may continue to increase. To account for the annual changes in the price of electrical energy, a separate PV analysis was conducted. In this analysis, it was assumed that the average price of electrical energy in 2007 is $74.0/MWh. It was further assumed that price of electrical energy would increase at a rate of 2.0% per year. With 2.0% growth in the annual price of electrical energy, the PV of total cost of 5L83 is expected to be $922 M less than the PV of total cost of the UEC alternative.

Figure 3-2 shows the difference in the PV of costs between UEC and 5L83 alternatives for annual growth in price of energy ranging between 1.0% and 10.0%:

Figure 3-2. Sensitivity Analysis Based on the Growing Price of Electrical Energy

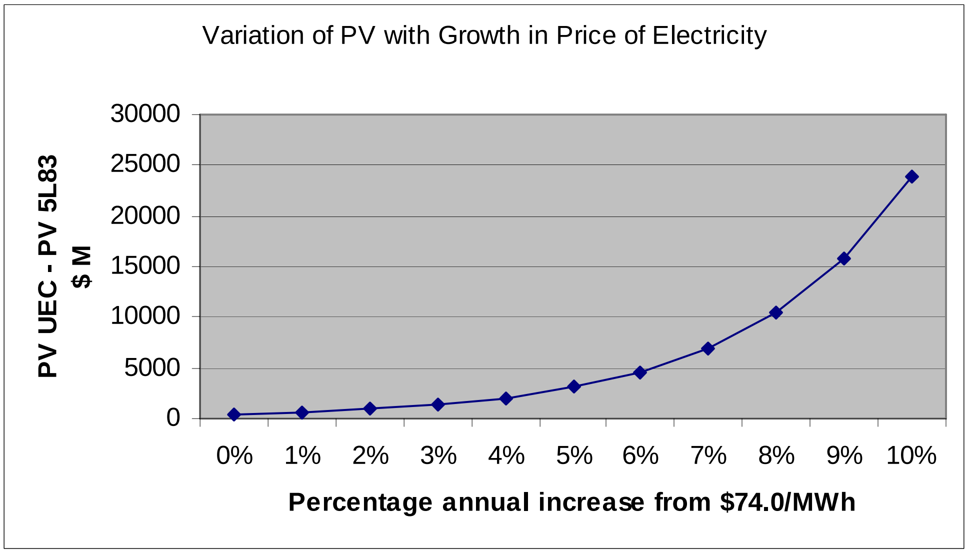


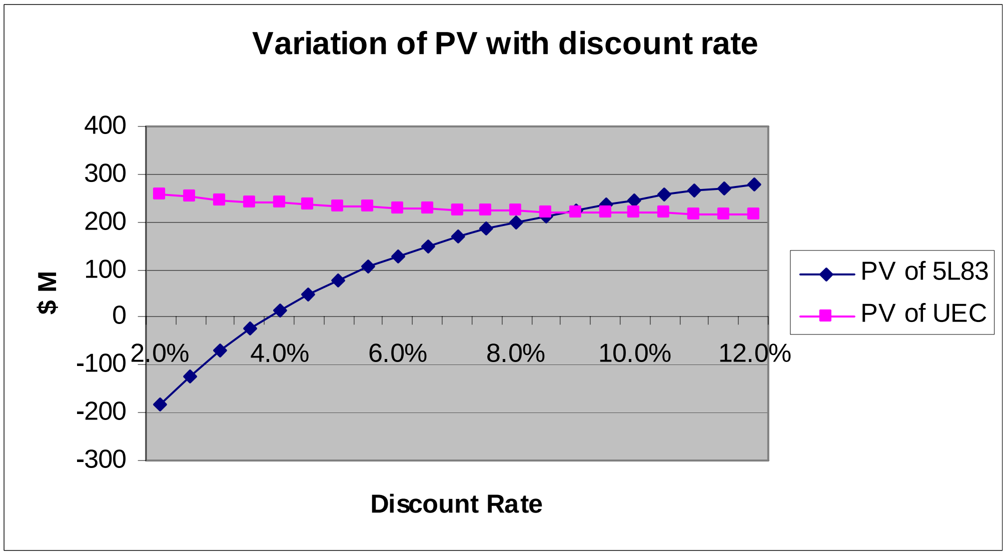
Figure 3-2 indicates that annual increase in the price of electricity would improve the attractiveness of 5L83 over UEC from a financial perspective.

3.5.2 Variation of PV with Discount Rate

In section 3.5, the PV analysis is based on applying a 2.50% real discount rate to the un-inflated costs of both 5L83 and UEC. A sensitivity analysis was conducted to evaluate the impact of changing discount rates on the PV comparison of the two alternatives. In this analysis, the difference in the PV of the alternatives was calculated for discount rates ranging from 2.00% to 12.00%. The average price of electrical energy was assumed fixed at $74.0/MWh. Other calculation parameters remained unchanged.

Results of the discount rate sensitivity analysis on the PV of total cost of alternatives are shown in Figure 3-3.

Figure 3-3. Sensitivity of the PV of Costs with Respect to Discount Rate



It is observed that as the discount rate increases, the difference between the PV of costs for the 5L83 and UEC alternatives decreases. The two alternatives would have similar PV of costs at an 8.8% discount rate.

3.5.3 Sequencing of 5L83 and UEC

In Section 3.5, the PV of cost of reinforcing the ILM grid with 5L83 was compared to a similar cost associated with the UEC alternative. The comparison was made assuming that 470 MVAr reactive power support would be installed prior to 2014 and then the ILM grid would be reinforced either with 5L83 or with the UEC. It was further assumed that no other ILM reinforcements would follow and the future growth in the coastal demand would be met by a combination of future increases in the Coastal Generation, DSM, and imports on the western inter-tie.

In this section, long-term planning sequences that are based on implementing both 5L83 and UEC alternatives are reviewed. Two sequences for implementing both 5L83 and UEC alternatives are defined and the PV of costs for each sequence is evaluated. The reviewed long-term planning sequences are:

(a) The 470 MVAr reactive power installation prior to 2014, followed by commissioning of 5L83 in 2014, followed by implementing a partial UEC in 2020.

The partial UEC would include all of the UEC upgrades listed in Table 3-1 except for the upgrade of summer ratings of 5L41, 5L42, 5L44, and 2L1 / 2L5.[12]

(b) The 470 MVAr reactive power installation prior to 2014, followed by completing all UEC upgrades in 2014, followed by the commissioning of 5L83 in 2019.

In the first long-term planning sequence, construction of 5L83 would increment the TTC of the ILM grid to approximately 6750 MW. It would also resolve thermal constraints of the ILM grid in summertime. The additional TTC would be consumed by 2020. Between 2014 and 2020 the ILM transmission loss reduction associated with 5L83 would be approximately 307 GWh/yr. In 2020, those UEC upgrades that are defined to enhance the TTC in wintertime would be implemented and would provide incremental TTC.

In the second long-term planning sequence, all of the UEC upgrades would be implemented by 2014. For this sequence, in 2014, the expected voltage stability limit of the ILM grid would increase to 6355 MW and its continuous thermal rating would increase to between 6000 MW and 6570 MW. The incremental TTC would be used by 2019. Between 2014 and 2019 no reduction in the ILM transmission losses would be expected. In 2019, 5L83 would be constructed and would provide incremental TTC.

Eventually, both long-term planning sequences have to be followed by another ILM reinforcement such as 5L46. However, 5L46 would be common between both sequences and its impact is not considered in this analysis.

Table 3-3 shows the PV of each long-term planning sequence as well as the difference between the PV of the planning sequences. All cost numbers are in 2007 un-inflated Dollars and include OH and IDC.

[12] If 5L83 were built first, then upgrading the summer ratings of the ILM circuits would not be required.

Table 3-3. PV of Long-Term Planning Sequences

Long-Term Planning Sequence # 1: 5L83 Followed by the Partial UEC								
		Costs in $1000						
1	Year	2014	2015	2016	2017	2018	2019	2020
2	NIC&MDN 470 MVAr	8,870	0	0	0	0	0	0
3	5L83	458,878	0	0	0	0	0	0
4	Partial UEC	0	0	0	0	0	0	109,076
5	Taxes	0	1,549	1,549	1,549	1,549	1,549	1,549
6	O&M	0	855	855	855	855	855	855
7	Total	467,748	2,404	2,404	2,404	2,404	2,404	111,480
8	PV (Seq. 1)	575,044						

Long-Term Planning Sequence # 2: UEC Followed by 5L83								
		Costs in $1000						
9	Year	2014	2015	2016	2017	2018	2019	2020
10	NIC&MDN 470 MVAr	8,870	0	0	0	0	0	0
11	UEC	190,231	0	0	0	0	0	0
12	5L83	0	0	0	0		458,878	0
13	Cost of ILM Losses	22,689	22,689	22,689	22,689	22,689	0	0
14	Taxes	0	909	909	909	909	909	2,373
15	O&M	0	892	892	892	892	892	1,664
16	Total	221,790	24,490	24,490	24,490	24,490	460,679	4,037
17	PV (Seq. 2)	724,575						
18	PV(Seq. 2) – PV(Seq. 1)	149,531						

This table shows that, from a PV of costs perspective, building 5L83 in 2014 and following it by a limited number of UEC upgrades in 2020 would be less expensive than implementing the UEC in 2014 and delaying 5L83 to 2019. The difference between the PVs of the two long-term planning sequences would be approximately $150 M and would be mainly attributed to the 5L83 transmission loss savings between 2014 and 2019.

From the point of view of redundancy of assets, the second long-term planning sequence would make the summer rating upgrades of 5L41, 5L42, 5L44, and 2L1 / 2L5 redundant after 2018. There would be no redundancy associated with the first long-term planning sequence.

In summary, it is concluded that from a cost and redundancy perspective, reinforcing the ILM grid with 5L83 would be the preferred first step in long-term planning of the ILM grid.

3.6 Double Outage Limitations

In this section, performance of the ILM transmission grid when two of its transmission lines are out of service is examined. The study identified the amount of generation and load shedding required for the reliable operation of the remaining grid.

During the light load season, when coastal demand is limited and there are opportunities for importing power from the US on circuits 5L51 and 5L52, steady state flows on the ILM grid are expected to be low. In such situations, it may be possible to withstand double outages of the ILM grid without overloading or destabilizing the remaining grid. Consequently, the need for generation and load shedding would be minimal.

The likelihood of surviving N-2 ILM outages diminishes as more Interior resources are dispatched to meet the LM and VI demand. With outages of two ILM lines, the increased flow from the Interior towards the LM would push the remaining ILM grid towards its thermal and voltage stability limits and may cause transmission instability. To relieve the overload and to maintain system stability, actions such as generation shedding in the Interior, load shedding in the LM and VI, and reduction of firm exports on 5L51 and 5L52 may become necessary.

One advantage of 5L83 over the UEC alternative is that with 5L83 built, double outages of either 5L81/5L82, 5L81/5L83 or 5L82/5L83 would not sever NIC from the LM. For any one of these double outages, there would remain one 500 kV circuit between NIC and the LM. The remaining link would provide at least 1835 MW[13] of transmission capacity to transfer Interior generation to the LM. The UEC alternative does not provide this additional transmission link. This link would be crucial when two of the NIC to LM lines are forced out of service.

To estimate the amount of load and generation reduction caused by the outage of two ILM transmission lines, both steady state load flow and dynamic stability of the

[13] The most restrictive remaining line would be either 5L81 or 5L82. The 1835 MW is based on the normal rating of AMC series capacitors (2.12 kAmp) on 5L81 or 5L82

2013/14 transmission network were examined. The export level on the western inter-tie was kept at 280 MW to represent BCTC's 230 MW long-term firm obligation and the 50 MW Transmission Reliability Margin (TRM). In real time, different levels of non-firm power would flow on the ILM grid. However, in this study, the non-firm export transactions were not directly considered. It was assumed that following a double outage the non-firm transactions would be the first to be curtailed.

Table 3-4 summarizes the results of the double outage analysis for the 5L83-reinforced grid. This table lists the required generation shedding in the Interior and load and firm export reduction in the LM under the most severe N-2 outages. Table 3-5 summarizes the results of a similar analysis for the UEC-reinforced grid.

Table 3-4. Load / Generation Shedding requirements for the 5L83-Reinforced Grid

	First Outage	Second Outage	Generation Shedding (MW)	Load & Firm Export Reduction (MW)
1	5L41	5L82	680	640
2	5L42	5L81	681	593
3	5L41	5L81	610	595
4	5L42	5L41	501	473
5	5L82	5L81	429	438
6	5L82	5L42	393	380

Table 3-5. Load / Generation Shedding Requirements for the UEC-Reinforced Grid

	First Outage	Second Outage	Generation Shedding (MW)	Load & Firm Export Reduction (MW)
1	5L41	5L82	1130	965
2	5L42	5L81	1430	1200
3	5L41	5L81	1080	938
4	5L42	5L41	1170	990
5	5L82	5L81	1659	1470
6	5L82	5L42	1648	1440

Tables 3-4 and 3-5 indicate that with the UEC upgrades, outages of 5L81 and 5L82 would cause the highest amount of generation shedding in the Interior and load shedding in the LM and VI. This is because when 5L81 and 5L82 are out, transfer of the Interior generation to the LM would mostly be limited to flows on 5L41 and 5L42. These two lines primarily carry Peace River generation. During high Peace River generation hours, 5L41 and 5L42 would not have enough capacity to carry a significant output from the South Interior (SI) generating plants. In comparison, 5L83 would reduce this constraint by providing a new NIC line to transfer some of the SI generation to the LM. Consequently, if 5L83 were built, the required N-2 generation shedding in the Interior, the load shedding in the LM and VI, and reduction of the US export would be reduced considerably.

Comparison of Tables 3-4 and 3-5 shows that:

(a) When two ILM lines are out, the generation and load shedding requirements of the 5L83-reinforced grid would be significantly less than similar requirements for the UEC-reinforced grid.

(b) Generation shedding requirements of the 5L83-reinforced grid would range from 450 MW (for outage of 5L41 and 5L82) to 1255 MW (for outage of 5L42 and 5L82) less than the generation shedding requirements of the UEC-reinforced grid.

(c) Load shedding requirements of the 5L83-reinforced grid would range from 325 MW (for outage of 5L41 and 5L82) to 1060 MW (for outage of 5L42 and 5L82) less than the load shedding requirements of the UEC-reinforced grid.

3.7 Probabilistic EENS Performance

To evaluate the probabilistic reliability performance of 5L83 and compare it against the UEC alternative, an EENS study was conducted. The study was based on the following system conditions and assumptions:

(a) The EENS performance of the 5L83 and UEC alternatives and Do-Nothing conditions were evaluated.

(b) The studied period was from 2013 to 2016. After 2016, the Do-Nothing network would be overloaded under N-0 conditions.

(c) The winter peak network load was based on the December 2005 normal load forecast.

(d) Peak hour Coastal Generation between 2013 and 2016 was kept at 2106 MW. The specified level of Coastal Generation is similar to the designated Coastal Generation in BC Hydro's Amended LTAP portfolio which remains constant between 2013 and 2016.

(e) Load flow cases and load duration curves were developed for both winter and summer seasons.

(f) The continuous ratings of the circuits were applied.

(g) The analyzed transmission outage data was based on the outage statistics of lines and transformers between 1986 and 2005.

(h) 5L83 was assumed to have a similar outage performance to 5L82.

(i) All generation sources were considered 100% reliable. The EENS was attributed only to the reliability performance of the 500 kV transmission grid.

(j) The EENS for summer and winter seasons were calculated separately. The sum of these values was considered to represent the annual EENS of the bulk transmission network.

(k) The interruption cost of one MWh of electrical energy was considered to be $5000. This value was used in the evaluation of EENS for the Vancouver Island Transmission Reinforcement Project.

Results of the EENS analysis are shown in Table 3-6. This table shows that the EENS for the Do-Nothing scenario can vary between 2000 and 4000 MWh/yr. After adding 5L83 or UEC, the EENS is expected to drop to between 120 and 180 MWh/yr. Although these numbers are based on a specific set of study assumptions, they are indicative of the reliability risk associated with the existing ILM grid and the role that ILM reinforcements play in managing that risk.

Table 3-6. Comparing the EENS Performance of 5L83 and UEC Alternatives

		2013/14	2014/15	2015/16	2016/17
1	EENS for 5L83 (MWh)	172	128	121	130
2	EENS for UEC (MWh)	180	127	151	143
3	EENS for Do-Nothing (MWh)	2153	2601	2965	4083
4	EENS Difference (MWh) "UEC" – "5L83"	8	0	29	13
5	EENS Interruption Cost Dif. ($M) "UEC" – "5L83"	0.041	0.000	0.147	0.064
6	Average EENS Difference (MWh/yr) "UEC" – "5L83"	12.57			
7	Average Cost Saving ($M) "UEC" – "5L83"	0.0628			

This table indicates that, in terms of EENS, both 5L83 and UEC alternatives cause similar improvements to the probabilistic reliability performance of the transmission network.

4.0 SUMMARY

BCTC reviewed the following transmission and non-transmission alternatives for providing increased transfer capability on the ILM grid:

(a) Upgrade-Existing-Circuits (UEC)

(b) New Line – 5L83

(c) New Line – 5L46

(d) New Line – NIC to ING

(e) HVDC

(f) Coastal Generation/DSM

Following the preliminary screening of the alternatives, 5L46, NIC to ING, HVDC, and Coastal Generation / DSM were set aside, and UEC and 5L83 were examined in detail.

Comparison of these two alternatives indicated that:

(a) For peak hour operating points when KLY transfers are between 1000 MW and 2000 MW, the continuous thermal capabilities of the UEC and 5L83 alternatives vary between 6000 MW and 6570 MW for UEC and between 6220 MW and 6750 MW for 5L83.

(b) For most peak hour operating points, the thermal overload capacities of the 5L83 and UEC alternatives are similar.

(c) With the addition of 470 MVAr reactive power support, the 5L83 and the UEC alternatives would increase the voltage stability of the ILM grid to 7120 MW and 6355MW respectively. Higher voltage stability levels for both alternatives would require excessive reactive power reinforcements and are not considered efficient.

(d) Compared to the UEC alternative, 5L83 would save approximately 307 GWh/yr in the ILM transmission losses.

(e) For energy valued at $74.0/MWh, the PV of costs for 5L83 would be $373.4 M less than the PV of costs for UEC alternative. The difference in the PV of costs is mainly attributed to lower transmission energy losses associated with 5L83.

(f) Building 5L83 in 2014 and following it by a limited number of UEC upgrades in 2020 would be less expensive than implementing the UEC in 2014 and delaying 5L83 to 2019. The difference in the PV of costs between the two long-term planning sequences would be approximately $150 M and would be mainly attributed to the 5L83 transmission loss savings between 2014 and 2019.

(g) Double outage generation shedding requirements for 5L83 would be between 669 MW and 1255 MW less than similar requirements for the UEC alternative.

(h) Double outage load shedding requirements for 5L83 would be between 517 MW and 1060 MW less than similar requirements for the UEC alternative.

(i) Both 5L83 and UEC reinforcement alternatives would make similar improvements in the EENS performance of the bulk transmission grid.

Table 4-1. Summary of the UEC / 5L83 Comparison

	Technical Indices	5L83	UEC	Comments
1	Thermal Capacity (Overload)	Aprox. 8400 MW	Aprox. 8400 MW	Defined by the N-1 thermal overload nomograms
2	Thermal Capacity (Continuous)	6220 MW to 6750 MW	6000 MW to 6570 MW	Defined by the N-1 thermal continuous nomograms
3	Voltage Stability Limit	Aprox. 7120 MW	Aprox. 6355 MW	With 470 MVAr additional reactive power support
4	Transmission Loss Savings	Aprox. 307 GWh/yr	None	Average ILM transmission loss savings in 2014/15
5	PV of Costs for Continuous TTC	$-121.9 M	$251.5 M	For energy valued at $74.0/MWh
6	Double Outage Gen. Shedding	393 MW to 681 MW	1080 MW to 1659 MW	Based on the N-2 shedding requirements
7	Double Outage Load Shedding	380 MW to 640 MW	938 MW to 1470 MW	Based on the N-2 shedding requirements
9	EENS	121 MWh/yr to 172 MWh/yr	127 MWh/yr to 180 MWh/yr	For the simplified bulk transmission network

5.0 CONCLUSION

It is the conclusion of this report that building a new transmission line, 5L83, is the preferred alternative for increasing the TTC of the ILM transmission grid.

APPENDIX A – PV TABLE AND TOOL

Table A-1. Comparison of Costs Between 5L83 and UEC Based on the Fixed Value of Electrical Energy ($74.0/MWh) and Continuous TTC.

	ILM OPTIONS with 2014 ISD	UNINFLATED COSTS 2014			OPERATING COSTS					Losses	PRESENT VALUES IN			2014
		Total Capital OH&IDC	OH	IDC	O & M		Taxes		Total Opr. Costs	Annual Value of Incremental Energy Losses	Total Cap OH&IDC	Operating Costs	Cap. Cost + OH + IDC + Opr. Cost	PV of Cap. Cost + OH + IDC + Opr. Costs + ILM Average Energy Losses
					T-Line	Station	T-Line	Station						
		$1,000	$1,000	$1,000	$1000/yr	$1000/yr	$1000/yr	$1000/yr	$1000/yr	$1000/yr	$1,000	$1,000	$1,000	$1000
1	5L83	467,747.9	13,047.9	50,581.5	326.6	528.7	1,009.9	538.6	2,403.9	(22,688.6)	467,747.9	69,883.3	537,631.2	(121,957.1)
2	UEC	199,101.0	5,788.8	13,842.3	-	892.2	0.0	909.0	1,801.2	0.0	199,101.0	52,363.8	251,464.7	251,464.7

For the PV spreadsheet tool used to calculate Table A-1, see the file:

ILM Alternatives PV Tool.xls