2012 Network Integration Transmission Service (NITS) System Impact Study (SIS) Report

FOR

BASE RESOURCE PLAN (BRP)

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EXECUTIVE SUMMARY

In response to Open-Access Same-Time Information System (OASIS) Transmission Service Request (TSR) #77321076, BC Hydro performed a series of transmission system studies and assessments to identify major transmission reinforcements required for the next 20 years. The study results are summarized in this system impact study (SIS) report.

In this study, the BC Hydro 500 kV bulk transmission system is divided into four regions: (1) the Northern Division where 500 kV transmission reinforcements are required to facilitate the integration of Site C and wind power development in the Peace Region, (2) the North Coast region where 500 kV transmission system upgrades are necessary to supply mining and oil & gas industrial load growth in North Coast and Northwest areas, (3) the South Interior region where transmission reinforcements are needed to accommodate the integration of Mica Unit 5, Mica Unit 6 and Revelstoke Unit 6, and (4) the Interior to Lower Mainland (ILM) transmission network where transmission system additions are needed to accommodate the interconnection of a new large pumped storage generating plant near Stave Lake. In addition, two regional transmission systems, the Peace Region and Metro Area, are studied in this report because of significant system configuration changes that are planned in the ten-year planning period.

The 2012 NITS Base Resource Plan (BRP) revised on 21 March 2013 and past transmission system assessments are key inputs for this study. Major transmission capital projects that are in project definition phase or execution phase as well as future (F2014 – F2033) transmission system reinforcement options are summarized in Appendix F. Smaller scale transmission system reinforcements identified in specific generation interconnection, load interconnection and area transmission system studies are not included in this report.

Since the completion of the studies described in this report, there have been some relatively minor changes to the load and resource data. Updated data was used in the development of the Integrated Resource Plan (IRP) that was approved by the Province of B.C. on 2013-Nov-25 and will be reviewed through the ongoing NITS update process.

BC hydro FOR GENERATIONS

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1.0 INTRODUCTION

This report was prepared in response to Open-Access Same-Time Information System (OASIS) Transmission Service Request and associated NITS System Impact Study (SIS) Agreement between BC Hydro Energy Planning ("Transmission Customer") and BC Hydro Grid Operations ("Transmission Provider").

This SIS report describes the major bulk transmission system reinforcements from F2014 to F2023 needed to provide adequate transmission services to the Transmission Customer and identifies potential long-term bulk transmission system strategic development plan for the planning period from F2024 to F2033. Regional transmission plans for the South Peace and Metro Vancouver regions are also included.

The studies associated with this report are based on (a) the 2012 Annual System Peak Load Forecast released on 23 January 2013, with 495 MW of incremental LNG and mining load added in the North Coast region, (b) the 2012 Transmission Voltage Customer Forecast released on 13 February 2013 and (c) the 2012 NITS Base Resource Plan (BRP) revised on 21 March 2013, all of which are summarized in Section 2.0.

The transmission system planning criteria and major assumptions regarding for resource dispatch are summarized in Section 3.0. Major bulk transmission requirements identified for each region in this study are described in detail in Section 4.0.

The transmission upgrade plans identified in this report may be modified and revised to include other alternatives as part of BC Hydro's normal system planning process. Subsequent steps in the capital planning process that include the development of the transmission portion of BC Hydro's capital plan and any necessary applications for Certificates of Public Convenience and Necessity (**CPCNs**) will require alternatives to be developed before the scope of a project can be recommended. The outcome may be different than the plans described in this SIS report. Due to circumstances that may change and other factors such as project implementation risks, the actual system reinforcements that get implemented could be somewhat different and perhaps considerably different from the upgrades described in this report.

2.0 NITS UPDATE DATA

The load forecast and generation resource plan (e.g. BRP) used in this study is summarized in this section.

In accordance with the OATT, Transmission Customers are required to provide a 10-year system load forecast and generation resource plans and subsequent updates to these plans for example the designation of new Network Resources or Network Loads. In addition to the ongoing updates that might have material changes impacting the system reliability, Transmission Customers are also required to provide annual updates to the load forecast and the projected generation resources.

2.1 Load Forecast

For this NITS SIS, the *2012 Annual System and Regional Load Forecast* provided on January 23, 2013 and later updated with 495 MW of incremental LNG and mining load in the North Coast (**NC**) region was used along with individual Transmission Customer Load data provided on February 13, 2013.

The reference system coincident load forecast with the impacts of Demand Side Management (DSM) programs and electric service rates (rate impacts) are summarized in Figure 1 and Appendix A. Note that this data does not include the 495 MW of additional LNG/mining load in the NC region.

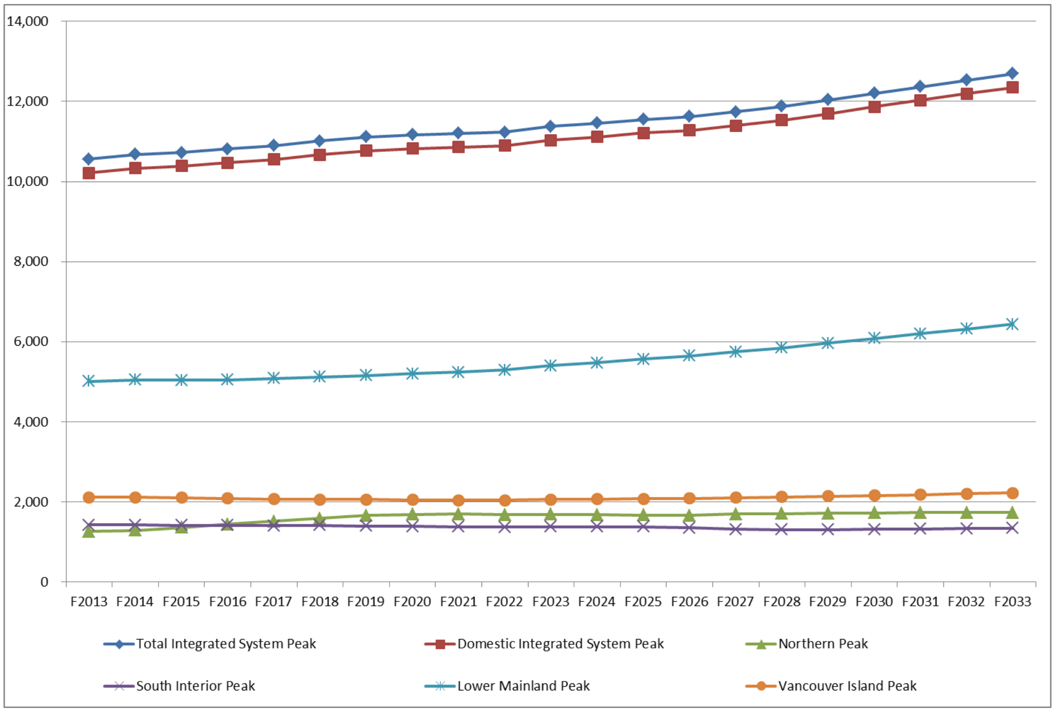

Figure 1: System Coincident Peak Load Forecast from F2013 to F2033

The system load forecast shows that the BCH system load increases at a moderate annual rate (0.75%) for the first 10 years in anticipation of economic conditions continuing to improve as well as the potential demand for load interconnections from the mining, and oil and gas explorations in the Northern Division. For the planning period from F2023 to F2033, the annual system load growth rate is approximately 1.1% which is mainly dominated by the Lower Mainland load growth.

BC Hydro system peak demand consists of distribution load and transmission voltage customer (TVC) load. Figure 2 shows the BC Hydro system transmission voltage customer load forecast from F2013 to F2033. Approximately 50% of the transmission voltage customer loads are located in the Northern Division electric system including oil & gas, mining, forest, industrial sectors, etc. Also, the Northern Division TVC load demand dominates the BC Hydro transmission voltage customer load demand in the next 20 years.

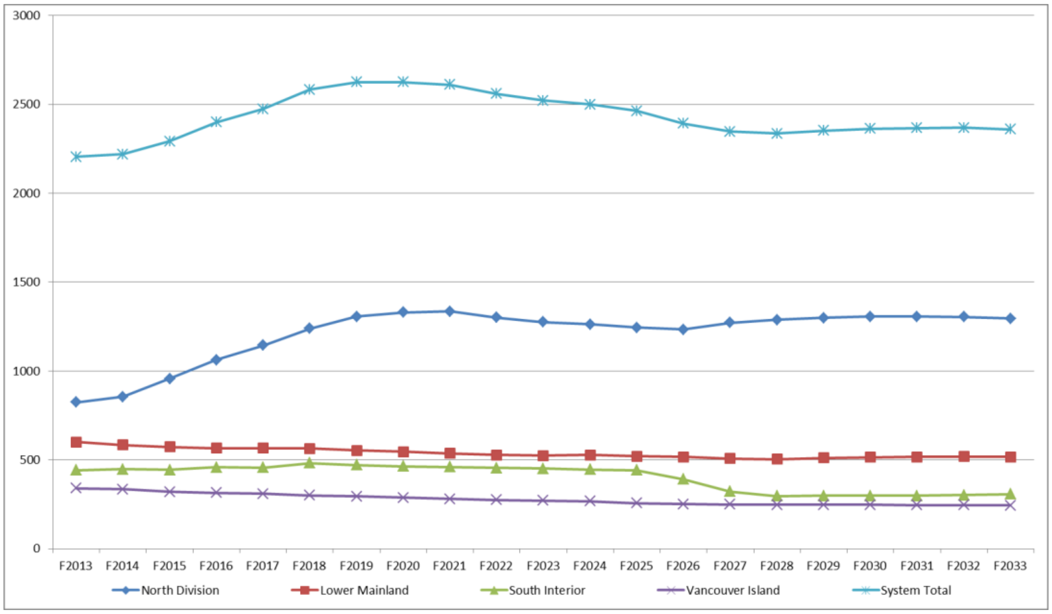

Figure 2: Transmission Voltage Customer Peak Load Forecast from F2013 to F2033

In addition to the annual BC Hydro system load forecast updates, BC Hydro Energy Planning and Economic Development included approximately 495 MW (including losses) of incremental North Coast LNG and mining loads in the 2012 BC Hydro BRP. These incremental TVC loads are included in the base case for the studies described in this report.

2.2 Base Resource Plan (BRP)

The BRP contains BC Hydro's generation resource plan for providing adequate generation capacity and energy required to meet the most likely load growth scenario. The BRP is used primarily for integrated transmission system planning and bulk transmission reinforcement project justification. The BRP is developed with a referenced system load forecast that includes the most likely DSM and Rate impacts. In addition to the generation projects currently under construction i.e. Mica Unit 5, Mica Unit 6, CPC2008 and CPC2010, major forecasted generation resources scheduled in the *2012 NITS Base Resource Plan BRP (Update)* issued on 21 March 2013 are summarized in Table 1.

Table 1: Major Forecasted Generation Resources in BRP

Data Source: NITS BRP - 21 March 2013

Major Future Generation Sources	Base Resource Plan (BRP) Nomination
Revelstoke Unit 6	488 MW, April 01, 2018
Site C Clean Energy Project	1100 MW, April 01, 2022
SCGT - KLY	196 MW, October 01, 2019
Peace Region Wind-farm Bundles	117 MW, October 01, 2029
	99 MW, October 01, 2030
Lower Mainland Pumping Storage Station	1000 MW, October 01, 2029
Future Small Hydro Generation Stations	MSW2_LM, 34 MW, October 01, 2030
	Holmes Hydro, 77 MW, July 01, 2014

3.0 PLANNING CRITERIA AND RESOURCE DISPATCHING ASSUMPTIONS

This section summarizes the transmission system planning criteria and generation dispatching assumptions used in this SIS.

3.1 Transmission System Planning Criteria

Standards that have been used in this study include:

- NERC Standards TPL-001, TPL-002, TPL-003, and TPL-004
- WECC Regional Business Practices
- Facility ratings, system operating limits and facility interconnection requirements as described in System Planning and Performance Assessment Mandatory Reliability Standards Manual, SPA2008-71.

3.2 Generation Dispatch Assumptions

The Transmission Customer has provided general guidelines on the dispatch of Network Resources to determine transmission requirements in this NITS study. Refer to Appendix B in section 6.2 for the definitions of the various generation capacity parameters. The major assumptions used in this study are summarized below:

I. In general[1], all generation plants in a sink area (or downstream) of the transmission cut-plane under review are dispatched to their DGC level both before and after first single contingencies.

II. For non-firm (N-0) transfer demand analysis:

1) System Load Levels: heavy winter, heavy summer and light summer.

2) Generation Dispatching Patterns and Assumptions:

a) Under normal system conditions, all plants in the source area under review (upstream of the transmission cut-plane) are dispatched to their seasonal Maximum Power Output (MPO) levels.

b) No generation reserves are modeled within the source areas.

III. For firm (N-1) transfer demand analysis:

1) System Load Levels Studied: heavy winter, heavy summer and light summer.

2) Generation Dispatch Patterns and Assumptions:

a) No generation reserves are modeled within a source area.

b) The total generation in a source area can be reduced to the aggregate System Capacity[2] (SC) level of that area to secure the system immediately following a first single contingency for all system load conditions except very light load conditions when there is a large surplus of dependable generating capacity in the system. This generation curtailment must be achieved automatically by Remedial Action Schemes (RAS).

Note that, for regional transmission cut-planes, the total aggregate upstream generation can be further reduced to 500 MW less than the aggregate SC[2] level. This is to be consistent with the practice of allowing clusters of generating plants with an aggregate SC value of

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[1] There may be exceptions in the case of thermal plants like Burrard (BGS) where the initial assumption is that it is operated at zero output or shut down and only committed as RMR in the interim period until specific system reinforcement are in place in according with Ministerial Order No. M314.

[2] System Capacity (SC) is equivalent to ELCC for intermittent plants. It is the capacity value assigned to the plant in Load-Resource Balance (LRB) tables.

up to 500 MW to be connected to the rest of the system via a single line.

c) For Bulk transmission studies of off-peak system load conditions, a larger amount of generation reduction is allowable (to less than the aggregate area SC level) to secure the system after a first single contingency because more back-up resources are available in the BC Hydro system during off-peak load conditions. However, the generation reduction should not trigger AGC suspension in real-time operation (presently this limit is 1200 MW for planning purposes).

4.0 BULK TRANSMISSION SYSTEM REINFORCEMENTS

Major bulk transmission system reinforcements for the F2014 to F2032 planning period identified in this study are described for the following regions: the Northern Division, North Coast, South Interior and Interior to Lower Mainland (ILM).

4.1 Northern Division 500 kV Transmission Corridor

The Peace Region is one of the largest power generation bases in British Columbia. Generation in the Peace Region includes Gordon M. Shrum (GMS) 3050 MW and Peace Canyon (PCN) 700 MW on the Peace River. The power generated in the Peace Region is transmitted to the Lower Mainland area via the Northern Division 500 kV transmission corridor from GMS/PCN to Kelly Lake substation (KLY) in the South Interior. As depicted in Figure 3, the Northern Division 500 kV transmission corridor consists of 5L1, 5L2 and 5L3/7 from GMS/PCN to Williston substation (WSN) and 5L11, 5L12 and 5L13 from WSN to KLY, all with 50% series compensation. Series capacitor stations are located at Kennedy Station (KDY) between GMS/PCN and WSN, and McLeese Station (MLS) between WSN and KLY.

With the GMS Generation Upgrade project and the addition of two wind farms (Bear Mountain and Dokie) in the South Peace area, the power transfer on this 500 kV transmission corridor will reach its voltage stability limit. To integrate the five new wind farms (Quality Wind, Bullmoose Wind Energy, Meikle Wind Energy, Tumbler Ridge Wind Energy and Wildmare Wind Energy) included in

CPC2008, a generation shedding scheme is required to secure the power system under first single system contingency (N-1) conditions instead of system reinforcement.

Because the Northern Division 500 kV transmission corridor has reached its transfer limits, future generation additions in the Peace Region such as Site C clean energy project (1100MW) and large scale wind power development in the South Peace area will trigger the need for 500 kV transmission system reinforcements from the Peace Region to South Interior.

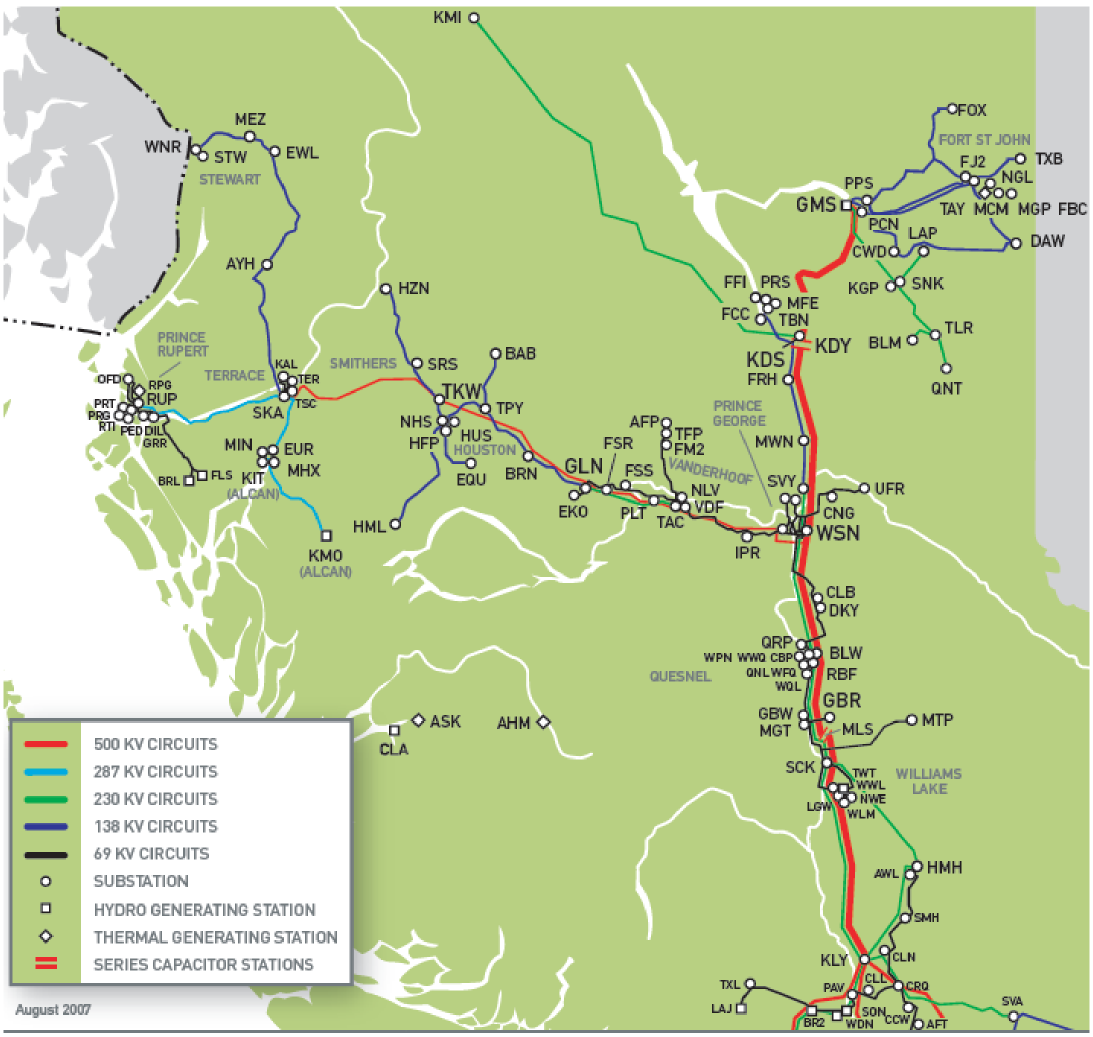

Figure 3: Northern Division Bulk Transmission System (2013)

In the BRP, the major generation additions in the Peace Region are the Site C Clean Energy project and new wind power bundles in the Peace Region, which are summarized as follows:

- Site C Clean Energy project is scheduled to enter service in F2023. The BC Hydro Standard Generation Interconnection System Impact Study and Facility Study recommends a new 500 kV substation near Site C generation station; Site C generation units will connect the Site C 500 kV substation via three short overhead lines. In addition, two parallel 500 kV transmission lines from the new Site C 500 kV substation to PCN generation station will be constructed on the existing 1L360 and 1L374 transmission right-of-way (more space will be acquired).
- From F2024 to F2031, two more wind power bundles (216 MW of total installed capacity) are projected to be in service by connecting to the Tumbler Ridge area transmission system. Consequently, by F2031, the total installed capacity of wind farms in the Peace Region will be approximately 900 MW, which is 7% of the system load at that time.

Although the BCH load forecast indicates that Peace Region has a higher load growth in next 20 years driven by a large amount of oil and gas explorations and extractions in Northeast BC, the Site C generation addition will further increase the Peace region generation surplus, which needs to be delivered to the major BC provincial load centers at Lower Mainland and Vancouver Island. The 20-year transfer demands on the Northern Division 500 kV transmission corridor are calculated and presented in Table 2 for the two 500 kV cut-planes: the South of GMS/PCN Cut-plane and South of WSN Cut-plane.

Table 2, Transfer Demands of Northern Division 500 kV Transmission Corridor[3]

Transfer Demand (MW)	2022 HW		2023 HS		2030 HW		2031 HS	
	MCR	ELCC	MCR	ELCC	MCR	ELCC	MCR	ELCC
South of GMS/PCN	4989	4346	5112	4473	5138	4227	5287	4505
South of WSN	3540	2915	3881	3302	3774	2935	4179	3457

After F2022, the transfer demands on the Northern Division 500 kV transmission corridor will exceed the transfer capabilities of the existing system; major 500 kV

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[3] Maximum Continuous Rating (MCR) is also referred as Maximum Power Output (MPO) as described in Appendix B - Generation Capacity Definition.

transmission system reinforcements are needed to meet the demand. Based on the present generation interconnection strategies for Site C Clean Energy project and future wind power developments in the Peace Region, three system reinforcement alternatives have been considered for 500 kV Northern Division transmission reinforcement:

Alternative 1:

Refer to Figure C1 in Appendix C.

By F2023:

i. Add additional15% series compensation for 5L1, 5L2 and 5L3/7 at KDY with the nominal ratings of 2730 Amps in 2022[4].

ii. Add additional 15% series compensation on 5L11, 5L12 and 5L13 at MLS with the nominal ratings of 2730 Amps by 2022[5].

iii. Increase thermal capacities of line 5L1, 5L2 and 5L3/7 to 2730 Amps of summer continuous rating (3000 Amps of overload rating) by 2022.

By F2033,

i. Add a +250/-150 Mvar SVC and a 250 Mvar MSC bank at WSN in 2029.

Alternative 2:

By F2023:

i. Construct a 500 kV transmission line (5L8) from PCN to WSN with 50% series compensation at KDY with the nominal rating of 2730 Amps in 2022.

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[4] This reinforcement can be achieved by adding a new capacitor platform or upgrading the existing capacitor banks, which will be considered as two engineering alternatives in Project Definition Phase

[5] Same as footnote #3

ii. Add additional 15% series compensation on 5L11, 5L12 and 5L13 at MLS with the nominal ratings of 2730 Amps by 2022.

By F2033,

i. Add a +250/-150 Mvar SVC at WSN in 2029.

Alternative 3:

By F2023:

i. Construct a 500 kV transmission line (5L8) from PCN to WSN with 50% series compensation at KDY with the nominal ratings of 2730 Amps in 2022.

ii. Construct a 500 kV transmission line (5L14) from WSN to KLY with 50% series compensation at MLS with the nominal ratings of 2730 Amps in 2022.

By F2033,

i. No further system reinforcement is identified.

In the subsequent steps of the bulk transmission system planning and transmission capital plan process, the alternatives will be further evaluated for the engineering feasibility and economics prior to any recommendation.

4.2 North Coast 500kV Transmission System

The North Coast bulk transmission system is a radial 500 kV transmission system approximately 460 km in length consisting of three 500 kV transmission lines (5L61, 5L62 and 5L63) in series extending from Williston substation (WSN) in the Central Interior to Skeena 500 kV substation (SKA) on the North Coast via Telkwa substation (TKW) and Glenannan substation (GLN). Each 500 kV substation is a major supply source to the local area sub-transmission systems which are not normally connected[6].

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[6] Physically, there is a 138 kV connection between TKW and GLN and a 66 kV connection between GLN and WSN, both operated normally open.

There are several generation stations connected to this North Coast system including the Falls River (FLS, 9.6 MW), Brown Lake (BRL, 7.2 MW), Prince Rupert (RPG, 46 MW) and Kemano generation station (KMO). RPG is a gas-fired generation station and presently operated as a backup (or emergency) source for the Prince Rupert area. KMO, the largest power source in this area is owned by Rio Tinto Alcan (RTA) and mainly supplies RTA load in Kitimat. A long-term purchase agreement between RTA and BC Hydro has been designated as a network resource in the NITS with a Dependable Generation Capacity (DGC) of 163 MW. Presently, there is no transmission constraint in the North Coast bulk system. Northwest Transmission Line (NTL) project is under construction and the target in-service date is 2014/2015. This 287 kV transmission line connecting the new Bob Quinn (BQN) substation to the Skeena (SKA) substation will facilitate the interconnection for potential mining loads in the Northwest area. 2L99 is the single line that connects the Kitimat area to main BC Hydro system and also interconnects RTA system to the BC Hydro system. Due to original design deficits and end of life issue, 2L99 has to be de-rated presently and needs to be rebuilt.

4.2.1 North Coast Transmission Demand Analysis

The Northwest Transmission Line project has facilitated several mining load transmission service requests (TSRs) that have been submitted on OASIS. In addition, a large amount of Liquefied Natural Gas (LNG) load demand is expected to develop in the Kitimat/Rupert area over the next 10 years. Based on the load forecast for the next 20 years, the transmission voltage customers in mining sector, forest industrial sector and LNG development will dominate the load growth in the North Coast area. The North Coast 500 kV transmission demands based on both the BC Hydro 2012 Load Forecast and the additional 495 MW of North Coast load nomination in 2012 NITS Update are summarized in the Figure 4.

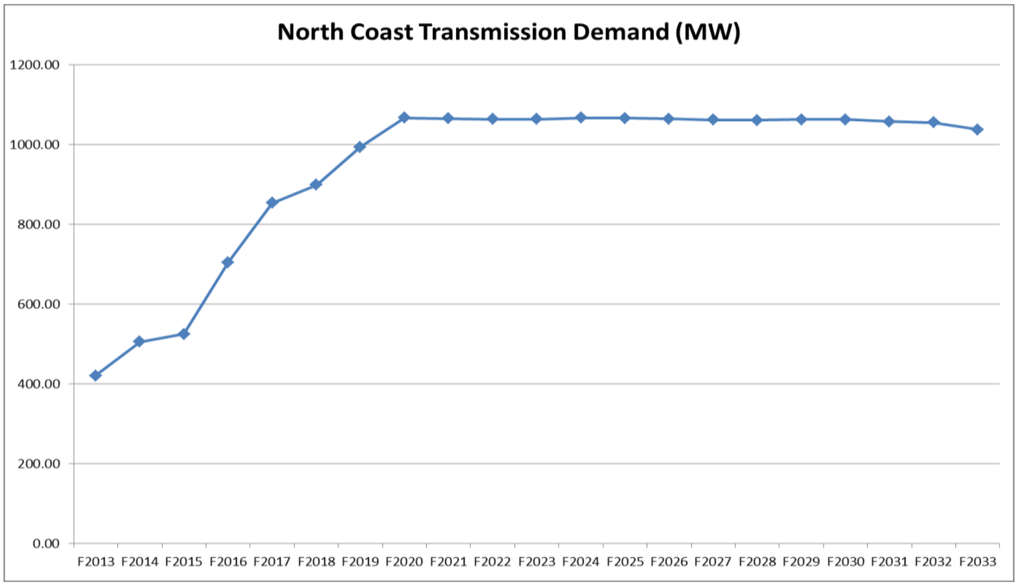

Figure 4, North Coast Transmission Demand from F2013 to F2033

Based on recent information update from the mining load development in Northwest area, several mining load customers would defer their in-service dates to after F2019 and the transmission demand was adjusted correspondingly as shown in Figure 5. Therefore, the North Coast transmission demand analysis is based on the adjusted demand.

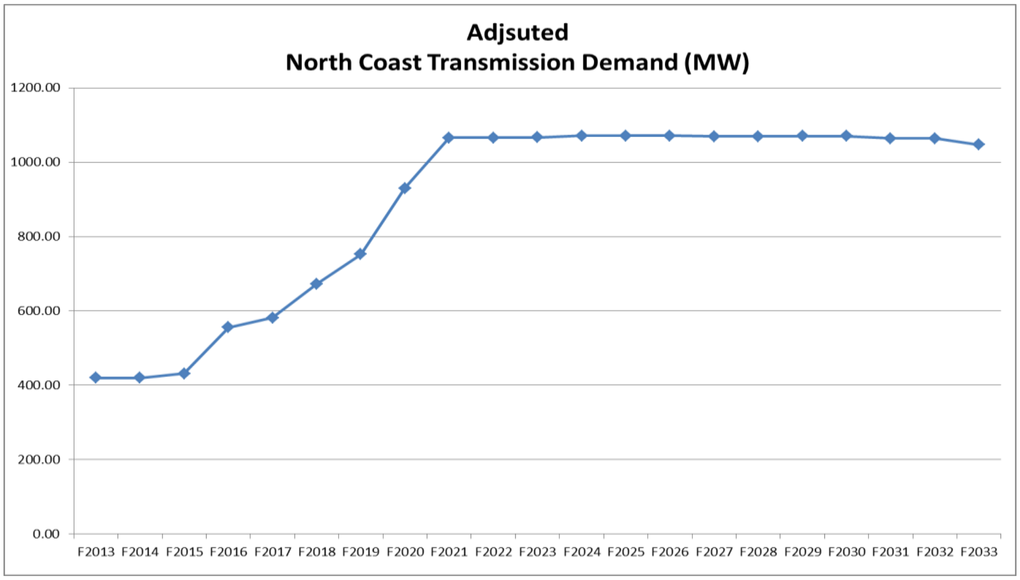

Figure 5, Adjusted North Coast Transmission Demand from F2013 to F2033

Because of the uncertainties of the industrial development in North Coast area, for example, the market impacts on the metal mine development, large LNG plant development in Kitimat/Rupert area, new pipeline project initiation, etc., the North Coast transmission demand could vary significantly year by year.

4.2.2 North Coast System Reinforcements

The existing 500 kV transmission lines 5L61, 5L62 and 5L63 cannot provide adequate transfer capability after 2018 based on the adjusted transmission demand analysis shown in Figure 5. Series compensation on 5L61, 5L62 and (or) 5L63 will be required and accordingly, the Prince George to Terrace Compensation (PGTC) project had been initiated including approximately 290 Mvar of mechanically-switched shunt capacitor banks (MSC) are needed at Glennan (GLN).

- The PGTC project along with the other reinforcements described above will increase the 500 kV transmission load supply capabilities from WSN to SKA and will be adequate for the transmission services to the industrial loads by 2019.
- The PGTC project does not change the North Coast 500 kV transmission system configuration. The power supply to SKA will be interrupted for the loss of any section line of the 500 kV circuits between Williston and Skeena. Loss of 5L61, in particular, could result in more than 1000 MW load rejection from BC Hydro system and such a significant system disturbance would be a challenge to system operations.

In addition, a third 500/287 kV transformer at Skeena (SKA) and 287 kV shunt capacitor banks are required to accommodate the transmission voltage load interconnections in North Coast area, including LNG and mining loads.

The above transmission demand analysis and system reinforcement are based on the following assumptions:

- The 156 MW import capacity from RTA is not committed as BC Hydro system Reliability-Must-Run (RMR)
- Post-contingency load shedding Remedial Action Schemes (RAS) are acceptable for any single contingencies of 2L103, 2L101, 2L99, 5L61, 5L62, or 5L63

4.3 South Interior 500kV Transmission System

The South Interior (SI) is another large generation base in British Columbia. The major generation stations in the SI are Revelstoke (2500 MW) and Mica (2000 MW) on the Columbia River. There are several other hydro generation plants operated by or contracted to BC Hydro in the South Interior East (SIE).

In the SIE, a few large hydro generation stations were built on the Columbia River, Pend-d'Oreille River, and Kootenay River. Selkirk substation (SEL) is a key system connection point that collects the electric power generated by Seven Mile (700 MW[7]), Kootenay Canal (580 MW), Arrow Lakes Hydro (190 MW) and the surplus generation from Fortis BC including Waneta, Brilliant, Brilliant Expansion, South Slocan, Lower Bonnington, Upper Bonnington and Corra Linn in the West Kootenay[8]area.

The SI bulk transmission system is assessed by three transmission cut-planes as depicted in Figure 6. The "West of Selkirk" cut-plane consists of 5L91 and 5L96 lines. Surplus power from Selkirk flows west through this cut-plane towards Ashton Creek and Nicola substations. The second cut-plane is "West of Ashton Creek/Selkirk", which consists of lines 5L76, 5L79 and 5L98. Power arriving at

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[7] Maximum observed continuous outputs

[8] The total maximum observed continuous generation output in FBC system is about 813 MW

Ashton Creek Substation from Revelstoke and power from Selkirk Substation flows through this cut-plane towards Nicola substation. The third South Interior transmission cut-plane is “Mica”, which consists of 5L71 and 5L72 and measures the power injection from Mica generation station.

Figure 6: South Interior Bulk Transmission System (2013)

With the addition of Revelstoke Unit 5 in 2010, the power transfers at these three cut-planes have now reached the cut-planes’ limits under heavy power transfer conditions. Generation-shedding remedial action schemes (RAS) have been implemented to secure the system under critical single system contingencies. For example, *i*) generation shedding could be required for Mica generation units when either 5L71 or 5L72 is lost; *ii*) generation shedding could be required from Seven Mile or Kootenay Canal or both when any one of 5L91, 5L96 and 5L98 is lost, especially during “Freshet” season. Any future generation additions including Mica Unit 5, Mica Unit 6, and Revelstoke Unit 6 as scheduled in the BRP will necessitate 500 kV transmission system reinforcements in SI.

4.3.1 South Interior 500 kV Transmission Capital Projects

1), Generation Shedding RAS Project for WAX

The Waneta Expansion generating plant (WAX) is designated as a BC Hydro Network Resource (NR) with zero DGC (DGC=ELCC=0.0MW) because WAX is not relied upon to provide winter dependable capacity to supply BC Hydro's domestic loads; WAX only contributes energy to the BRP and CRPs. Shedding generating capacity to below the aggregate ELCC value of the plants "upstream" of a cut-plane is not normally permitted in planning studies. In this case, however, it is acceptable to shed to below the aggregate ELCC level in the SIE region because that requirement occurs under light loading conditions when the total system generating capacity reserve level is greater than 15%. Because shedding down to less than the aggregate ELCC value would not materially affect system reliability, the existing SIE system generation shedding scheme will be extended to the WAX units. There is no major transmission system reinforcements proposed for integrating the WAX generating plant.

2), Seymour Arm Series Capacitor (SASC) Station Project

To integrate the peaking units in Mica generation plant as designated in BRP, a series compensation project (including two series capacitor station on 5L71 and 5L72 respectively) is under construction and is expected to enter service in 2014. With the SASC project in-service, the MCR of Mica generation capacity can be delivered into the system under system normal condition and its DGC generation capacity can be delivered to Nicola substation when either 5L71 or 5L72 is out of service during the system peak load condition.

3), Nicola Substation Reconfiguration

With the addition of peaking units in Mica and Revelstoke generation plants, power flow over the Interior to Lower Mainland (ILM) system via Nicola substation (NIC) will increase significantly. Most of the source lines enter NIC from the northeast side of the substation while most of the load lines exit from the southwest side. Because a large amount of electric power flows through the 500kV main buses, any bus outage will result in a severe overload on the other 500 kV main bus. Further, NIC is a critical substation in the BC Hydro transmission system because it connects nine 500 kV lines that carry more than half of provincial power supply flowing through this substation under heavy power transfer conditions. Multiple system contingencies may cause the loss of the whole NIC and consequently result in large area black-out in BC electric power system.

Nicola station reconfiguration project was initiated to alleviate the 500 kV main bus overloads and reduce the forced outage rate of the 500 kV main buses and the risk of multiple system contingencies related to Nicola substation. Nicola station reconfiguration project is presently in the Execution Phase and expected to be in service in 2014. The project scope includes:

i. The replacement of 500 kV bus conductor
ii. The re-termination of 5L71, 5L76 and 5L81, and
iii. The addition of two 500 kV circuit breakers at the high sides of NIC transformers T2 and T3.

4.3.2 South Interior Transmission System Reinforcements

The last peaking unit to be installed on the Columbia River is Revelstoke Unit 6. In the BRP, It is scheduled to enter service in F2019. Revelstoke Unit 6 (500 MW) is the major generation addition in South Interior; an additional 500 MW power injection (approximately) will further flow to NIC substation via the West of ACK/VAS cut-plane. To facilitate the integration of Revelstoke Unit 6, the following system reinforcement will be required to increase the transfer capability of the west of SEL 500 kV transmission system:

a. 50% series compensation on 5L98 with target ISD of 2018-Oct-01; a new series capacitor station will be built near the middle point of 5L98 transmission line, named “Trout Creek” series capacitor station.

b. A 500 kV 250 Mvar mechanically switched capacitor (MSC) has been proposed at NIC with ISD of 2018-Oct-01; this facility is required for firm transfer capability from Mica to Nicola substation and maintain system voltage level at NIC substation,

4.4 Interior to Lower Mainland (ILM) Transmission System

The ILM system, shown in Figure 7, consists of eight 500 kV transmission lines including 5L81, 5L82, 5L42, 5L41, 5L87, 5L40, 5L44 and 5L45 that connect NIC and KLY in the South Interior to CBN, MDN, ING and CKY in the Lower Mainland. The ILM transmission cut-plane, comprising 5L41, 5L42, 5L81, 5L82 and a 230 kV circuit, 2L90, is a critical transmission path in BC because it transmits electricity from the Interior where the majority of the generation is located to the major provincial load centers in the Lower Mainland and Vancouver Island, which together comprise approximately 70% of the provincial demand.

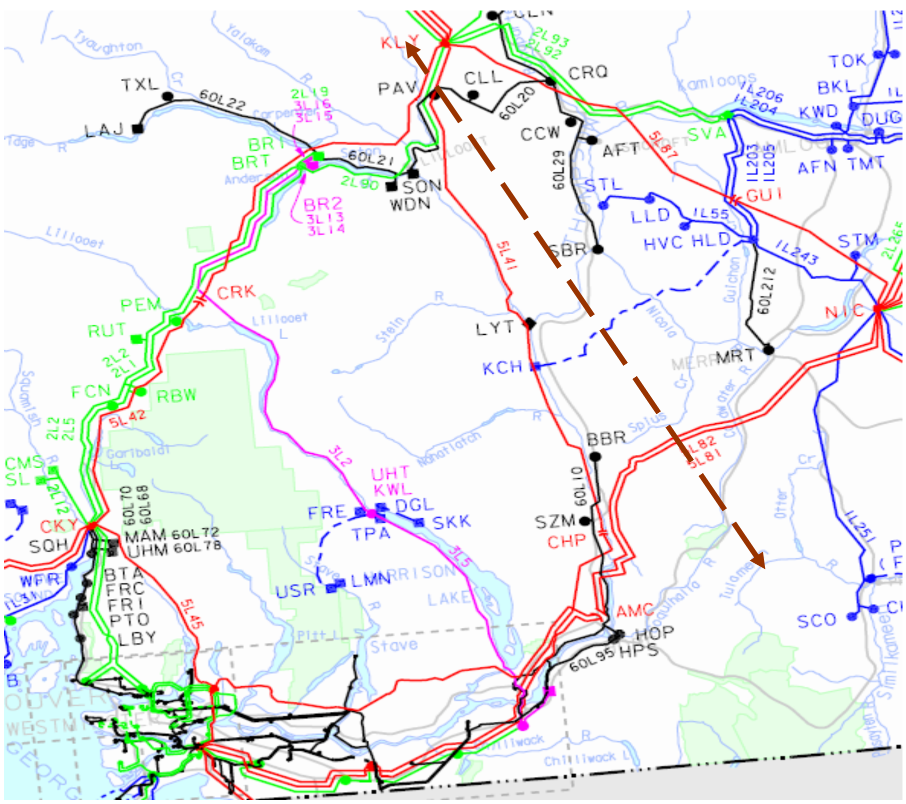

Figure 7: Interior to Lower Mainland (ILM) Transmission System (2013)

Presently, with the consideration of 905 MW DGC from BGS, there is no transfer capability shortfall on the ILM transmission cut-plane and the ILM transmission system is capable of providing adequate firm transmission capability to meet the peak transfer demand prior to 5L83; after that, BGS will no longer be available for transmission planning purposes.

The 500 kV Interior to Lower Mainland (ILM) transmission system reinforcement project, 5L83, is under construction and is forecast to enter service by summer 2015. This new series-compensated 500 kV transmission line that is being built from Nicola (NIC) substation to Meridian (MDN) substation is expected to increase the firm transmission capacity of the ILM transmission cut-plane to approximately 6550 MW. In addition, by adding some MSCs, the transfer capability of the ILM cut-plane could reach 7120 MW in future before any major 500 kV transmission reinforcement is required.

4.4.1 Transfer Demand Analysis for the ILM Transmission System

According to the system configuration shown in Figure 7, the transfer demand at the ILM transmission cut-plane is a function of:

- Load demand growth in the Lower Mainland and Vancouver Island,
- Firm exports to the US (e.g., power export to Seattle City Light), and
- Dependable generation resources in the Coastal area.

In summary,

Transfer Demand = Load Demand[9] *+ Firm Export – Dependable Generation*

The forecasted transfer demands at the ILM transmission cut-plane are depicted in Figure 8.

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[9] The load demand in the formula accounts for losses as well.

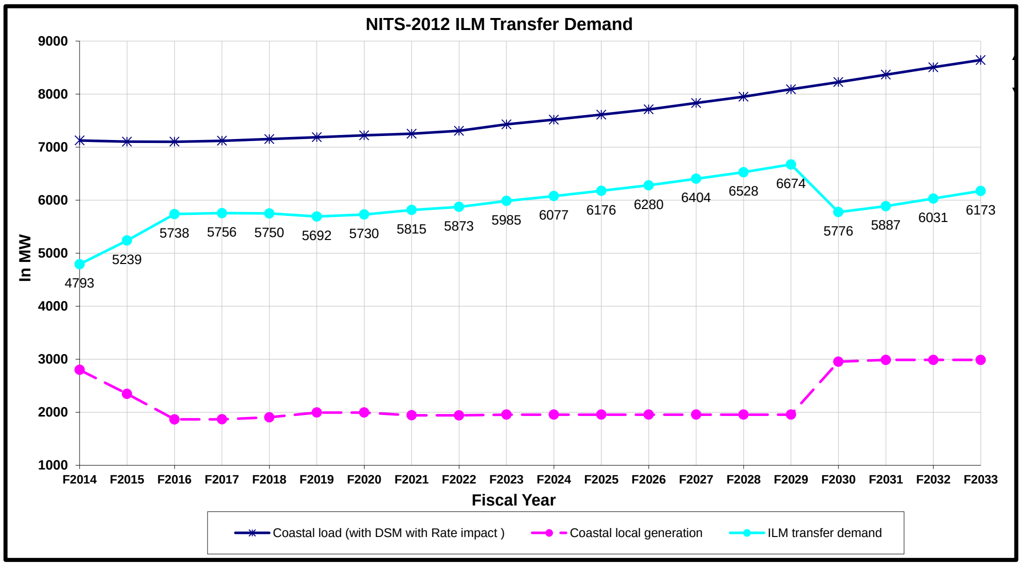

Figure 8: Total Generation (BRP) and Load in LM and VI

Observations of the ILM transfer demand analysis:

- In the near term, BGS thermal generation retirement from transmission planning perspective dominates the increase of ILM transfer demand
- In the long term (after 2020), load growth in Lower Mainland (LM) and Vancouver Island (VI) dominates the transfer demand increase in an average annual rate of 1.6% till to 2029 after which a new 1000 MW pumped storage generating station is added at Stave Lake
- The addition of the Lower Mainland Pumped Storage Generating Station (1000 MW) significantly reduces the ILM transfer demand from the interior to Lower Mainland

4.4.2 ILM Transmission System Reinforcements

Based on the ILM transfer demand analysis results in Section 4.4.1, there is no major 500 kV ILM transmission system reinforcement required in the 20-year planning period except for facilities required to interconnect the 1000 MW pumped storage station at Stave Lake.

The generation data of the LM Pumped Storage station are summarized as follows based on NITS Data Update and the input from Energy Planning and Economic Development:

- Location: Kenyon site in the Stave Lake area, which can be located at coordinates: “49.40249, -122.27222”
- Generator Type: Synchronous generators which are able to work in pumping mode
- Generator Terminal Voltage: 16.0 kV
- Generation Capacity: Zero to 1000 MW at any time of the day or night in any season
- In-Service Date: October 01, 2029
- Load Impact: Assuming that the pumped storage plant would operate in pumping mode during system light load conditions, the impacts on the existing BC Hydro transmission system are expected to be minimal and are not assessed in this NITS SIS report

Three generation integration options have been assessed as depicted in Figure 9 (a) to (c). The preliminary transmission system reinforcement requirements are proposed for these options.

Figure 9 (a), Interconnection Option 1 for the new Lower Mainland Pumped Storage Generating Station.

Option 1: Point of Interconnection at 5L82 (or 5L83)

For this option, two alternatives have been considered:

Alternative 1:

1. Construct a new 500 kV switching station near LM Pumped Storage station, and
2. Build two 500 kV transmission lines, each 20 km in length; and loop 5L82 (or 5L83) into the new 500 kV switching yard.

Alternative 2:

1. Construct a new 500 kV switching station to sectionalize 5L82 (or 5L83); and
2. Build two 500 kV transmission lines, each 20 km in length, from the LM Pumped Storage station to the new 500 kV switching station.

With this option, under heavy ILM power transfer conditions, 5L44 outage may cause cascading overload of 230 kV Metro systems.

Therefore, transmission system between MDN and ING may need to be reinforced; for example, a new 500 kV circuit between MDN and ING.

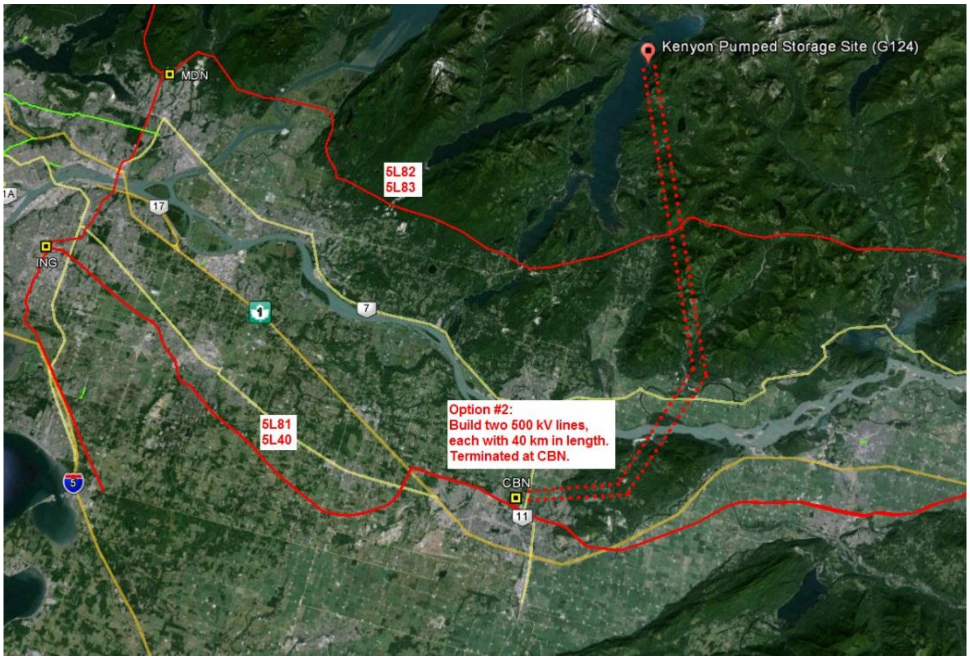

Figure 9 (b), Interconnection Option 2 for the new Lower Mainland Pumped Storage Generating Station.

Option 2: Point of Interconnection at CBN Substation

For this option, two 500 kV circuits, each approximately 40 km in length, will be constructed from LM Pumped Storage station to Clayburn Substation (CBN).

Figure 9 (c), Interconnection Option 3 for the new Lower Mainland Pumped Storage Generating Station

Option 3: Point of Interconnection at 5L82 (or 5L83) and CBN Substation

For this option, one 500 kV circuit, approximately 20 km in length, will be constructed from LM Pumped Storage station to a new 500 kV switching station connected to 5L82/5L83. The other 500 kV circuit, approximately 40 km in length, will be constructed from LM Pumped Storage station to Clayburn Substation (CBN).

These options provide a few generation integration concepts for the Lower Mainland Pumped Storage station at Stave Lake. The generation integrated solutions shall be detailed in a standard generation interconnection system impact study.

5.0 MAJOR REGIONAL TRANSMISSION SYSTEM REINFORCEMENTS

Due to high load growth rate in the planning period and major regional transmission system reinforcement projects needed in the 10-year planning period, Peace Region area transmission system reinforcement plan and Metro North area transmission development plan are summarized in this section.

5.1 Peace Region Transmission System Development Plan

The Peace regional transmission system consists of 230 kV and 138 kV transmission infrastructures radially supplied from GMS, which is the only major power source to the Peace Region. Three wind power projects (Bear Mountain Wind, Dokie Wind, and Quality Wind) have been interconnected with an installed capacity of 388 MW. Presently, the transmission capacity of the existing system to serve load and export wind generation has been fully utilized; load shedding schemes had been applied to secure the system under emergency conditions including some critical first single transmission contingencies (N-1).

5.1.1 Peace Region Load Forecast and Resource Development

Peace Region is expecting substantial load growth in the oil and gas sector because of the conventional and shale gas exploration and extraction, primarily in the Dawson Creek and Groundbirch areas over the next 30 years. Figure 11 and Figure 12 show the Peace Region load forecast and the load forecast for Dawson Creek and Groundbirch areas over the next 30-years.

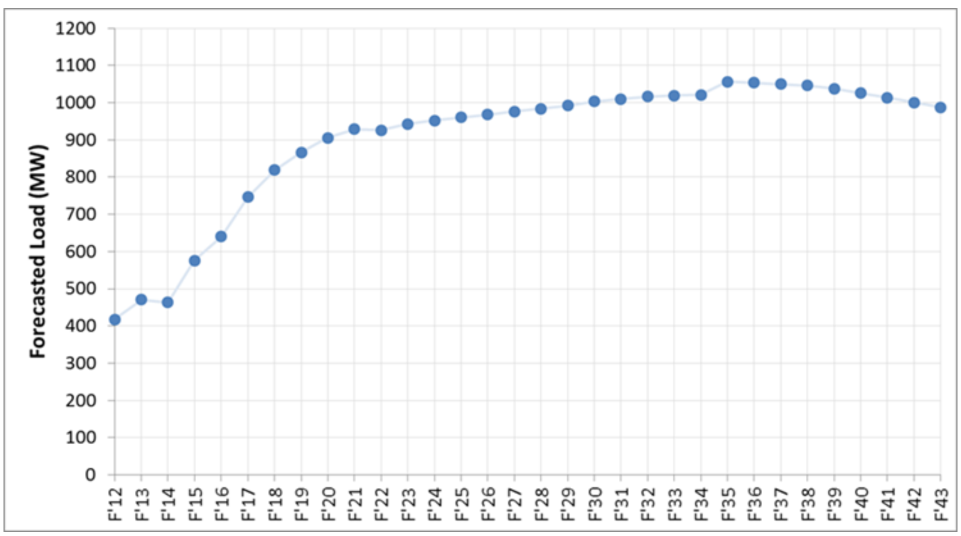

Figure 11, Peace Region Load Forecast from F2014 to F2043

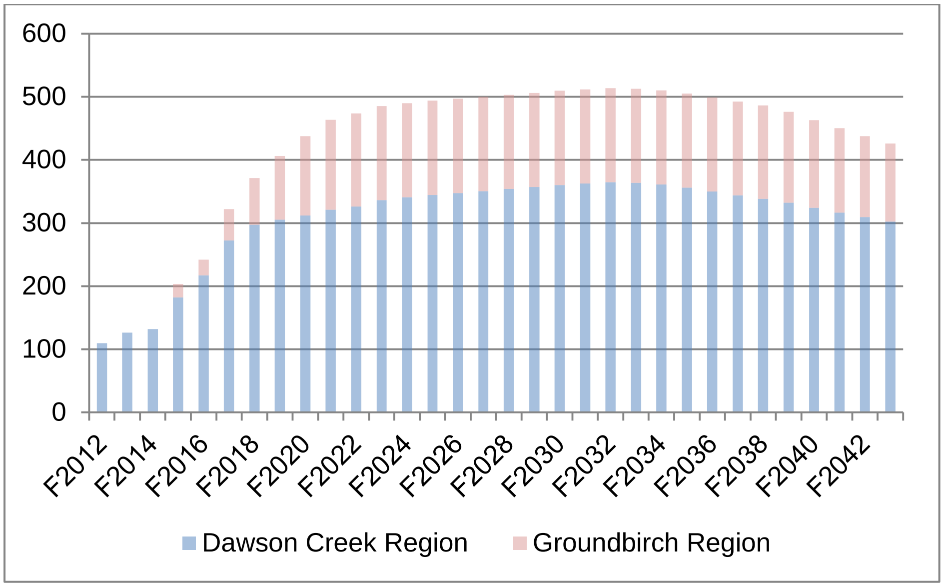

Figure 12, Load Forecast (in MW) for Dawson Creek and Groundbirch from F2014 to F2043

As designated in the BRP and shown in Table 3, several new wind farms are anticipated to be developed in Tumbler Ridge area; these will connect to the 230 kV transmission corridor that extends towards Tumbler Ridge from Sukunka substation.

Table 3, Future Wind Power Development in Peace Region

Projects	Size (MW)	In-service Date
Tumbler Ridge Wind Energy Project	47.2	F2015
Meikle Wind Energy Project	117.0	F2016
Wildmare Wind Energy Project	77.4	F2016
Bullmoose Wind Energy Project	60.0	F2017
BC Wind Bundle PR19	117.0	F2030
BC Wind Bundle PR21	99.0	F2031

In general, wind farms are energy based generation resources and not dependable for firm load supply service. For BC Hydro system wide load/source balance analysis, a wind farm's Effective Load Carrying Capability (ELCC) is approximately 21% of its installed capacity. For specific region or area system, the ELCC could be much less than 21% of its installed capacity. Therefore, in Peace Region, oil and gas industrial load growth will dominate the regional transmission demand in the planning period.

Site C Clean Energy Project (thereafter named Site C) is the largest hydro generation project in BC Hydro's 20 year plan. Two 500 kV transmission lines have been proposed to connect Site C generation station (1100 MW) to Peace Canyon (PCN). Starting year 2022, a new 500/138 kV step-down substation is required to provide power supply to Fort St. John and surrounding areas because the existing 1L374/1L360 transmission right-of-way (ROW) will be used for new Site C – PCN 500 kV lines.

5.1.2 Peace Region Transmission Capital Projects

To supply the near-term load growth, primarily in the Dawson Creek and Groundbirch areas, Dawson-Chetwynd Area Transmission (DCAT) project is in progress. This project was granted a Certificate of Public Convenience and Necessity (CPCN) in 2013 and has an expected in-service date of June 2015. The DCAT project will resolve the capacity shortfall from GMS to Dawson Creek and Groundbirch areas and will be able to accommodate some near-term oil and gas load interconnections under system normal conditions (N-0).

The DCAT project consists of the following transmission reinforcements (refer to Appendix D Figure D-1 for diagram):

- Tie the 230 kV and 138 kV systems together with a new 230/138 kV substation named Sundance Substation (SLS)
- Construct two 230 kV transmission lines from SLS to Bear Mountain Terminal Substation (BMT).
- Construct two new 230 kV transmission lines (operated at 138 kV) between BMT and Dawson Creek Substation (DAW).

To secure the system under some critical first single contingencies and multiple contingencies, this project will be accompanied by two remedial action schemes: the interim Peace Region Load Shedding RAS and the North Peace River Area RAS. The Peace Region Load Shedding RAS will initiate load shedding at key sites across the Peace Region to secure the system for all single and credible double contingencies while the North Peace River Area RAS will provide generation shedding and runback capabilities to resolve regional and bulk system overloads and voltage excursions in addition to providing anti-islanding tripping to the wind farms.

5.1.3 Transmission Reinforcements from F2019 to F2022

After the DCAT project enters service, the Peace Region load continues to increase and will exceed the N-0 capabilities that the DCAT project can provide in F2019. Therefore, additional transmission reinforcements in Peace Region will be required to provide adequate transmission capabilities to the Groundbirch and Dawson Creek areas to accommodate further oil and gas industrial load interconnection requests. A new Peace Region transmission reinforcement project (named as Peace Region Electric Supply (PRES) project) has been initiated based on the 30-year base load forecast. The scope of PRES is currently in identification phase and three alternatives are currently being investigated.

Alternative 1: Build a 230 kV Transmission Circuit GMS - SNK - SLS

For a depiction of this alternative, refer to Appendix D Figure D-2.

1) Replace the existing two 500/230 kV 300 MVA transformers at GMS (GMS-T13 and GMS-T14) with two 500/230 kV 600 MVA transformers

2) Construct a new 73 km long 230 kV overhead transmission circuit from GMS to Sukunka Substation (SNK), including

    a. The minimum conductor rating acceptable for this circuit is 1280 Amps or 510 MVA at winter rating (0˚C) and 1055 Amps or 420 MVA at summer rating (30˚C)

    b. Terminate the new 230 kV overhead transmission circuit at both GMS 230 kV switchyard and SNK 230 kV switchyard

3) Construct a new 30 km long 230 kV overhead transmission circuit from SNK to SLS, including

    a. The minimum conductor rating acceptable for this circuit is 1280 Amps or 510 MVA at winter rating (0˚C) and 1055 Amps or 420 MVA at summer rating (30˚C)

    b. Terminate the new 230 kV overhead transmission circuit at both SNK 230 kV switchyard and SLS 230 kV switchyard

The scope of this alternative could be expanded to supply load scenarios higher than the base load forecast, should that be required. This would be achieved by:

- Increasing the rating of the new 230 kV circuit between GMS to SNK and SNK to SLS to 2386 Amps or 950 MVA winter rating (0˚C) and 1742 Amps or 694 MVA summer rating (30°C)
- Re-conductoring the existing 2L308, 2L309 and 2L312 to the same rating

Alternative 2: Build a 230 kV Transmission Circuit GMS - DKT - SLS

For a depiction of this alternative, refer to Appendix D Figure D-3.

1) Replace the existing two 500/230 kV 300 MVA transformers at GMS (GMS-T13 and GMS-T14) with two 500/230 kV 600 MVA transformers.

2) Construct a 23 km long 230 kV overhead transmission circuit from GMS to DKT, including

    a. The minimum conductor rating acceptable for this circuit is 1280 Amps or 510 MVA at winter rating (0°C) and 1055 Amps or 420 MVA at summer rating (30°C)

    b. Terminate the new 230 kV overhead transmission circuit at both GMS 230 kV switchyard and DKT substation

3) Construct a 64 km long 230 kV overhead transmission circuit from DKT to SLS, including

    a. The minimum conductor rating acceptable for this circuit is 1280 Amps or 510 MVA at winter rating (0°C) and 1055 Amps or 420 MVA at summer rating (30°C)

    b. Terminate the new 230 kV overhead transmission circuits at both DKT and 230 kV switchyard

The scope of this alternative could be expanded to supply load scenarios higher than the base load forecast, should that be required. This would be achieved by:

- Increasing the rating of the new 230 kV circuit between GMS to DKT and DKT to SLS to 2386 Amps or 950 MVA winter rating (0˚C) and 1742 Amps or 694 MVA summer rating (30˚C)
- Re-conductoring the existing 2L308, 2L309 and 2L312 to the same rating

Alternative 3: Build a New 500/230kV Substation (PIV) Looping 5L2 in and Build a 230kV Transmission Circuit PIV - SNK - SLS

For a depiction of this alternative, refer to Appendix D Figure D-4.

1) Construct a new 500/230 kV substation (PIV) near Pine Valley and loop 5L2 into the substation
   a. The location of PIV is assumed to be where Highway 97 (John Hart Highway) departs from circuit 5L2 toward the east
   b. Two 500/230 kV 600 MVA transformers will be installed
   c. Relocate 500 kV line shunt reactor at GMS (known as GMS 5RX2) to PIV for the circuit section from PIV to KDY
2) Construct a new 52 km long 230 kV overhead transmission circuit from PIV to SNK, including
   a. The minimum conductor rating acceptable for this circuit is 1280 Amps or 510 MVA at winter rating (0°C) and 1055 Amps or 420 MVA at summer rating (30°C)
   b. Terminate the new 230 kV overhead transmission circuit at both PIV substation and SNK 230 kV switchyard
3) Construct a new 30 km long 230 kV overhead transmission circuit from SNK to SLS, including

a. The minimum conductor rating acceptable for this circuit is 1280 Amps or 510 MVA at winter rating (0°C) and 1055 Amps or 420 MVA at summer rating (30°C)

b. Terminate the new 230 kV overhead transmission circuit at both SNK 230 kV switchyard and SLS 230 kV switchyard

The scope of this alternative could be expanded to supply load scenarios higher than the base load forecast, should that be required. This would be achieved by:

- Increasing the rating of the new 230 kV circuit between PIV to SNK and SNK to SLS to 2386 Amps or 950 MVA winter rating (0°C) and 1742 Amps or 694 MVA summer rating (30°C)
- Re-conductoring the existing 2L308, 2L309 and 2L312 to the same rating, or
- Building a second 230 kV overhead transmission line from PIV to SLS

Alternative Comparison

The identification phase is ongoing and therefore the scope of these alternatives may change or additional alternatives may arise. At this time, the Alternative 2 is leading from transmission planning perspective for the following reasons:

- Alternative 2 requires up to 25% less 230 kV transmission lines compared to Alternative 1
- Alternatives 2 requires up to 10% less 230 kV transmission lines compared to Alternative 3
- Shorter transmission lines reduce cost and improve reliability.
- Alternative 2 minimize environmental footprint and cost by not requiring any new substations to be constructed
- Alternative 2 provides an opportunity to expand DKT such that future 230 kV line terminations would be available in the GMS

area. Only one 230 kV line termination remains at GMS after PRES.

5.1.4 Peace Region Transmission Reinforcements after F2023

With Site C generation interconnection in F2023, two 500 kV transmission lines will be built from Site C substation to PCN on the same ROW as 1L360/1L374. Because 1L360/1L374 are critical supply circuits to the Fort St. John Area, two new 500/138 kV transformers will be installed at Site C substation after 1L360/1L374 are decommissioned and the remaining line sections of 1L360/1L374 in Fort St. John area will be re-terminated to Site C substation (refer to Appendix D Figure D-5 for this configuration). However, due to further load demand increase in the Dawson Creek and Groundbirch Load Forecast, the Fort St. John area system configuration change for Site C generation interconnection cause the following system concerns from F2023:

1. 1L377 overloads under system normal conditions and after loss of either GMS-SLS transmission circuit resulting in 1L377 severe overloads
2. 1L360 (STC-TAY) overloads during 1L374 (STC-FJN) out of service, or vice versa
3. The overloads above increase from F2023 to F2032 as the area system loads increase in both Fort St John and Dawson Creek

Two planning alternatives have been considered to resolve these issues.

Alternative 1: 1L377 Normally Open (N.O.) at DAW

This alternative alleviates the 1L377 overload under normal system conditions as well as post-contingency overloads on 1L374 and 1L360 in F2023. Operating with 1L377 open under normal system conditions, is an effective and low-cost method to alleviate 1L377 overload; and it also simplifies system operation scenarios.

From transmission system planning and operation perspectives, 1L377 de-couples the Dawson Creek 138 kV system from Fort St. John 138 kV system. With the load growth in Groundbirch and Dawson Creek areas, thermal upgrade (or re-conductor) of 2L309 GMS-SLS 230kV and 138kV circuits will be required to increase post-contingency thermal capacity of the South Peace transmission system while additional reactive power compensation devices may be required at SLS or SNK to increase South Peace transmission system voltage stability limits. With load growth in the Fort St. John area, re-conductoring 1L374 and 1L360 will alleviate the post-contingency thermal overload of 1L374 or 1L360; otherwise, a new 138 kV circuit (approximately 12 km) from Site C substation to either TAY or FJN will be required.

Alternative 2: Adding a Phase-Shifting Transformer on 1L377 at TAY

Adding a 150 MVA, ±40^{o} phase shifting transformer (PST) in series with 1L377 at TAY will alleviate the 1L377 overload under system normal conditions. If the power transfer of 1L377 from TAY to DAW is pre-set properly under system normal conditions, the post-contingency transmission line 1L374 or 1L360 overloads will be alleviated after losing either 1L360 or 1L374.

In addition, a thermal protection scheme will be applied to prevent 1L377 or PST overload while a transfer tripping 1L377 Remedial Action Scheme (RAS) will be applied to prevent 1L360 or 1L374 overload after losing 1L374 or 1L360. Furthermore, re-conductor of 1L360 from Site C to TAY and 1L374 from Site C to FJN may be required to resolve the post-contingency overload on 1L360 and 1L374 when Fort St. John area load increases significantly after F2028.

Other alternatives, for example, new 230 kV (or 138 kV) transmission between the Fort St. John area (e.g. Site C substation, etc.) and Dawson Creek or Groundbirch area, will be considered if the load growth in Dawson Creek and Groundbrich areas are significant and higher than the base load forecast scenario.

5.2 Metro Region Transmission System Development Plan

Metro region is the largest load center in the province serving the load of Vancouver, Burnaby, Coquitlam / Tri-Cities, Richmond and New Westminster. Metro regional transmission system is a 230 kV network supplied from 500 kV Meridian Substation (MDN) located in North Coquitlam and Ingledow Substation (ING) in Surrey. As shown in Figure 13, the Metro regional system consists of two area systems: the Metro North system supplied predominantly from MDN and the Metro South system supplied predominantly from ING. Currently, there are two 230kV ties between these systems: one is 2L22 & 2L27 from MDN to ING via Whalley Substation (WHY) and the other is 2L53 from Murrin Substation (MUR) and Mainwaring Substation (MAN). Circuit 2L53 is near end of life, and has been zero-rated for planning purposes.

Metro region load demand continuously grows at a relatively steady rate of approximately 2% annually. A regional transmission reinforcement project, Vancouver City Central Transmission (VCCT), is under construction and is expected to be in service in early 2014. This project includes a new 230/12 kV substation named Mount Pleasant Substation (MPT) and two new 230 kV underground circuits 2L20 from Cathedral Square Substation (CSQ) to MPT and 2L44 from MPT to Sperling Substation (SPG), which establishes a new 230 kV tie between the Metro North and the Metro South systems to replace the end-of-life 2L53.

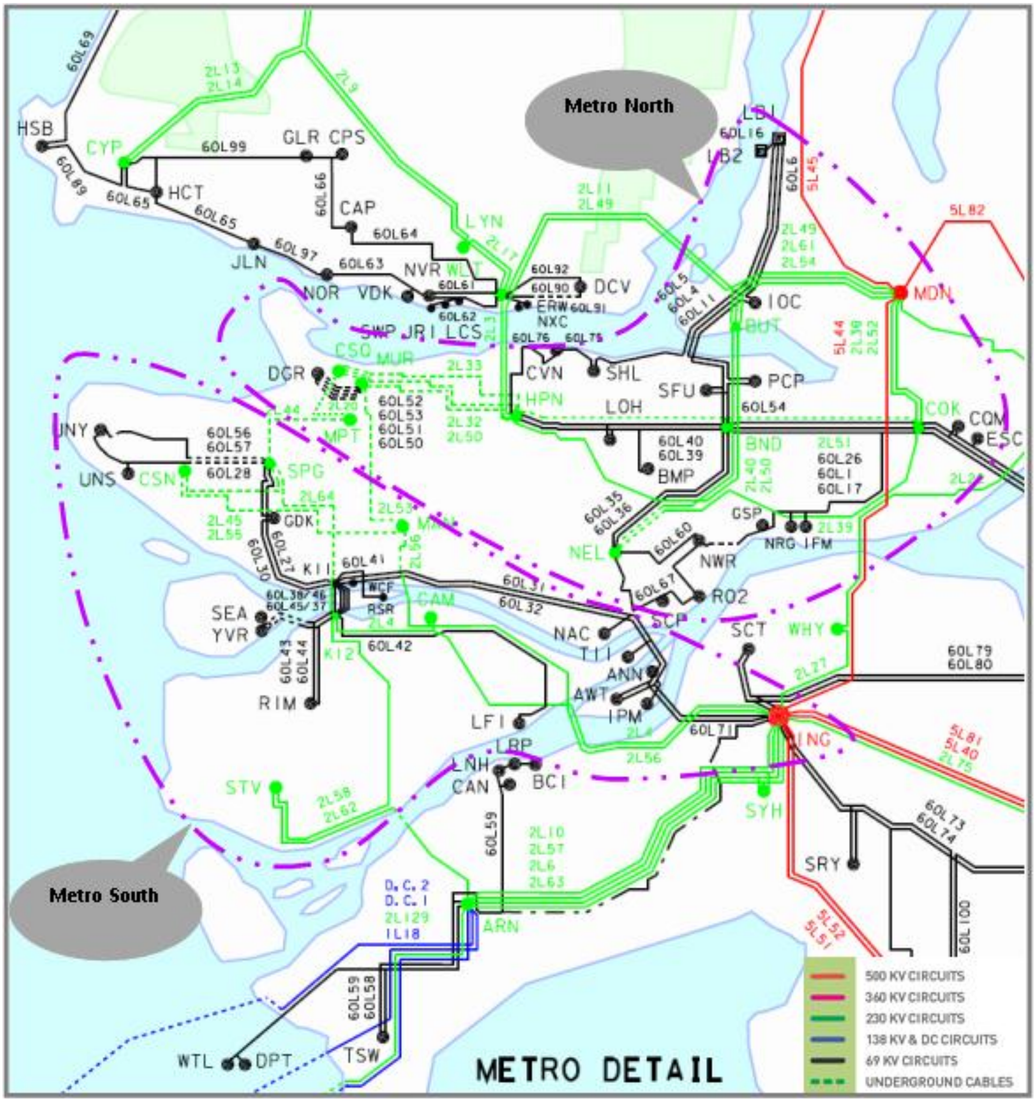

Figure 13, Metro Regional Transmission System (2014)

5.2.1 Metro Region Load Forecast

In the Metro Region, most of the loads are supplied through BC Hydro distribution system, and transmission voltage industrial customer load is less than 7% of the total area load. The Metro area 30-year (F2013-F2043) load forecast is depicted in Figure 14. The annual average load growth rate is approximately 2.27% from F2013 to F2023 and is 1.95% from F2023 to F2043 respectively.

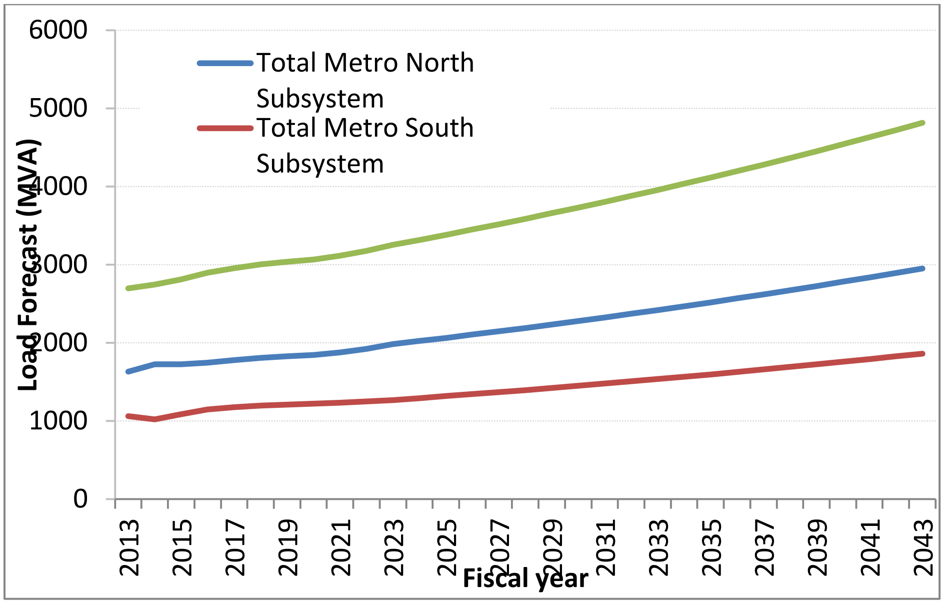

Figure 14, Thirty-year (F2013-F2043) Metro region load forecast

5.2.2 System Constraints

Local load growth in the Metro region is one of the key factors contributing to the constraints of the Metro North 230 kV transmission system. However, planned system configuration changes also contribute to the system constraints by increasing the power flow on the Metro North 230 kV transmission network. The major system configuration changes are *i*) the installation of a third Meridian 500/230 kV transformer (MDN T2) in service by August 2014 and *ii*) the addition of a second 500 kV transmission line (5L83) between Nicola and Meridian by January 2015.

System Constraints on West of Burrard Thermal Station

One of the major Metro North system constraints is on the west of Burrard Thermal Station (BUT) transmission path, which consists of four 230 kV transmission circuits 2L11, 2L49, 2L50 and 2L51; this path transfers power westward to the North Shore, Burnaby and Vancouver areas. Because these circuits consist of a mixture of overhead and underground circuits operating in parallel and have different lengths, the power flow does not distribute equally among these four circuits and it results in the heaviest loading (percentage of its thermal rating) on 2L51 under system normal (N-0) and after single contingencies (N-1). By winter 2016, the following thermal constraints are observed on the west of BUT transmission path, under single contingency events.

Contingency	Violations
Loss of circuit 2L11	thermal overload on circuit 2L51
Loss of circuit 2L49	thermal overload on circuit 2L51
Loss of circuit 2L50	thermal overload on circuit 2L51
Loss of circuit 2L51	thermal overload on circuit 2L50

If any first single contingency of the four circuits occurs, approximately 50 MW to 100 MW load need to be curtailed during the winter peak load period in 2016.

System Constraints on West of Horne Payne Substation

2L53 transmission circuit is near end of life and is planned to be decommissioned by 2017. The decommissioning of 2L53 will increase power flows on 2L32 and 2L33 that connect to Cathedral Square Substation (CSQ) to support the Metro South system and 2L44 from MPT to Sperling Substation (SPG). From summer 2019, loss of 2L33 will result in a thermal overload on 2L32.

5.2.3 Metro North Transmission Project

To meet the 30-year long-term power supply requirements to Metro area, three system reinforcement alternatives were proposed for further review in project identification phase of Metro North Transmission project (Target ISD – 2018).

Alternative 1: Como Lake-Horne Payne Transmission

As shown in Figure E-1 in Appendix E, this alternative will construct a new 19.8 km long 230 kV overhead transmission from Como Lake

Substation (COK) to Horne Payne Substation (HPN) and re-terminate 2L51 from HPN to MPT with an 8.7 km long 230 kV underground cable extension.

Alternative 2: Meridian-Horne Payne Transmission

As shown in Figure E-2 in Appendix E, this alternative will construct a new 21.5 km long 230 kV transmission circuit (10.5 km overhead line and 11.0 km underground cable) from MDN to HPN via the Burrard Inlet crossing and re-terminate 2L51 from HPN to MPT by extending 2L51 with an 8.7 km long 230 kV underground cable.

Alternative 3: Como Lake-Mount Pleasant Transmission

As shown in Figure E-3 in Appendix E, this alternative will construct a new 27.0 km long 230 kV underground cable from COK to MPT.

5.2.4 Evaluation of alternatives

Alternative 2 is the leading alternative from system planning perspective due to the following reasons:

- The lowest 30-year Present Value (PV).
- Alternative 2 provides the highest firm area power supply capability among all the alternatives.
- Alternative 2 offers the lowest cumulative transmission energy losses for the given planning period.

5.2.5 Long-term Metro Area Transmission Development Plan

Metro Vancouver Strategic Supply Plan[10] provides a high-level assessment of the different outlooks for meeting the long-term (30-year) load growth in the Metro area. This supply plan is currently being updated

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[10] Submitted as a part of the Vancouver City Central Transmission Project (VCCT) CPCN application to British Columbia Utilities Commission (BCUC), Sep. 2009.

with the most recent assessments, and the updated version is expected to be submitted in 2014 to the British Columbia Utilities Commission (BCUC) along with the CPCN application for the Metro North Transmission Project. The project scopes for the Metro area from F2014 to F2033 are summarized in Table F-2. It should be noted that the reinforcements beyond 2018 have been studied only at a preliminary level, and each will require detailed assessment in the future. Therefore, the final outcome may be different from the plans suggested in Table F-2.

6.0 APPENDICES

Appendix A: Summary of 2012 BCH System and Regional Load Forecast with DSM and Rate Impact

	Distribution Substation		Transmission Customer		Native Load	Wholesale	Export	Transmission Losses	Total Integrated System Peak	Domestic Integrated System Peak	Northern Peak	South Interior Peak	Lower Mainland Peak	Vancouver Island Peak
	Non-Coincident	System Coincident	Non-Coincident	System Coincident	System Coincident	System Coincident	System Coincident	System Coincident	System Coincident	System Coincident	NI Coincident	SI Coincident	System Coincident	System Coincident
	(MVA)	(MW)	(MVA)	(MW)	(MW)	(MW)	(MW)	(MW)	(MW)	(MW)	(MW)	(MW)	(MW)	(MW)
F2012	8,799	7,837	2,366	1,418	9,256	246	100	717	10,319	10,054	1,278	1,364	4,805	2,111
F2013	8,883	7,913	2,205	1,432	9,345	302	123	786	10,556	10,213	1,265	1,427	5,008	2,115
F2014	8,945	7,968	2,220	1,486	9,454	305	123	795	10,677	10,334	1,290	1,427	5,045	2,119
F2015	8,940	7,963	2,293	1,536	9,499	306	123	799	10,727	10,384	1,367	1,420	5,036	2,105
F2016	8,938	7,961	2,399	1,614	9,576	308	123	805	10,811	10,468	1,449	1,418	5,050	2,089
F2017	8,965	7,985	2,474	1,663	9,648	309	123	811	10,891	10,548	1,517	1,408	5,081	2,075
F2018	9,009	8,024	2,584	1,735	9,760	311	123	820	11,013	10,670	1,589	1,416	5,123	2,065
F2019	9,067	8,075	2,625	1,776	9,851	312	123	828	11,114	10,771	1,663	1,402	5,162	2,060
F2020	9,117	8,119	2,626	1,781	9,901	314	123	832	11,170	10,827	1,691	1,391	5,206	2,050
F2021	9,158	8,157	2,612	1,772	9,929	316	123	834	11,202	10,860	1,700	1,383	5,244	2,042
F2022	9,229	8,220	2,559	1,737	9,957	319	123	837	11,235	10,892	1,684	1,376	5,297	2,042
F2023	9,399	8,371	2,521	1,713	10,084	321	123	847	11,375	11,032	1,686	1,383	5,399	2,060
F2024	9,499	8,460	2,500	1,700	10,160	323	123	853	11,459	11,116	1,680	1,380	5,478	2,068
F2025	9,621	8,568	2,463	1,676	10,244	324	123	860	11,552	11,209	1,671	1,382	5,562	2,076
F2026	9,746	8,680	2,393	1,629	10,309	324	123	866	11,622	11,279	1,667	1,353	5,648	2,088
F2027	9,900	8,817	2,348	1,599	10,416	326	123	875	11,739	11,396	1,695	1,315	5,748	2,107
F2028	10,046	8,947	2,336	1,591	10,538	326	123	884	11,871	11,528	1,711	1,304	5,849	2,123
F2029	10,207	9,091	2,353	1,602	10,693	328	123	897	12,041	11,698	1,721	1,312	5,967	2,143
F2030	10,369	9,235	2,363	1,609	10,845	328	123	909	12,205	11,862	1,730	1,320	6,082	2,163
F2031	10,534	9,383	2,368	1,612	10,995	329	123	922	12,369	12,026	1,736	1,328	6,200	2,183
F2032	10,702	9,532	2,369	1,613	11,145	329	123	934	12,532	12,189	1,739	1,338	6,317	2,203
F2033	10,869	9,681	2,360	1,607	11,288	331	123	946	12,688	12,345	1,737	1,349	6,433	2,222
F2034	11,027	9,822	2,350	1,600	11,422	333	123	957	12,835	12,492	1,735	1,358	6,545	2,241
F2035	11,185	9,963	2,391	1,627	11,590	335	123	970	13,018	12,675	1,761	1,368	6,658	2,260
F2036	11,343	10,104	2,392	1,628	11,732	335	123	982	13,171	12,828	1,757	1,384	6,770	2,279
F2037	11,500	10,243	2,343	1,593	11,836	337	123	991	13,287	12,944	1,723	1,395	6,882	2,296
F2038	11,655	10,382	2,326	1,582	11,964	337	123	1,001	13,424	13,081	1,715	1,403	6,992	2,314
F2039	11,808	10,519	2,305	1,568	12,086	339	123	1,011	13,559	13,216	1,706	1,408	7,103	2,331
F2040	11,961	10,654	2,286	1,555	12,209	339	123	1,021	13,692	13,349	1,699	1,412	7,212	2,347
F2041	12,112	10,789	2,251	1,523	12,312	341	123	1,029	13,805	13,462	1,660	1,430	7,323	2,363
F2042	12,261	10,923	2,223	1,504	12,426	341	123	1,039	13,929	13,586	1,643	1,437	7,431	2,378
F2043	12,410	11,055	2,193	1,474	12,529	342	123	1,047	14,041	13,698	1,611	1,448	7,541	2,393

Note: this table does not include the 495MW of incremental NC LNG/Mining load.

Appendix B: Generation Capacity Definitions[11]

This section provides a brief explanation of the various generating capacity terms. For any particular plant, each of these values may vary seasonally. For example, due to seasonal variations in reservoir elevations, GM Shrum and Mica have higher maximum power output (MPO) ratings and dependable generating capacity (DGC) ratings in August than in February.

Maximum Power Output[12] (MPO): This is the maximum output that the generating unit or plant is capable of producing. The MPO value is the highest output that the plant would be able to produce under the most favourable conditions (e.g., maximum head for hydro plants and coldest weather for gas turbines) considering the season.

Dependable Generating Capacity (DGC): This is the capacity that a plant/unit can reliably provide for a required duration (3 hours/day to 16 hours per day depending on the local region's load shape and the plant's position in the dispatch order) each weekday during the two-week peak load period of the time of year (month or season) being studied. The DGC of a plant is the maximum capacity that can be committed as Reliability-Must-Run (RMR) capacity to defer transmission upgrades into a load area and hence it must have a very high confidence level.

Effective Load-Carrying Capability (ELCC): This is the incremental amount of load demand that an intermittent plant can supply when it is added to the system based on maintaining the 1 day in 10 years Loss of Load Expectation (LOLE) generating capacity adequacy criterion. The ELCC of an intermittent resource like a wind farm is the capacity that is equivalent to that of a conventional generating plant (e.g., large reservoir hydro plant) in terms of load supply reliability. The ELCC of an intermittent resource is the amount by which the load duration curve in an LOLE study can be shifted up when the intermittent resource is added to the resource stack while keeping the LOLE index value the same as before the addition of the intermittent resource. EPED considers reserve requirements when determining the future generating capacity additions in the LRBs.

System Capacity (SC): This is the capacity value used in the Load-Resource Balance tables and graphs. The SC of an intermittent resource like a wind farm or RoR hydro plant is equal

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[11] Generation capacity definitions are from Appendix 2D of the 2013-Nov-15 IRP.
[12] The IEEE definition of "maximum power output (hydraulic turbines): The maximum output which the turbine-generator unit is capable of developing at rated speed with maximum head and maximum gate."

to its ELCC value. The SC of a large hydro plant and any other non-intermittent resource is equal to its DGC value.

Reliability-Must-Run Generating Capacity (RMR): This is the minimum level of generating capacity that a generator owner commits to have on line during peak load periods. Committing to providing less RMR generating capacity in a load centre would have the effect of advancing the need to reinforce the transmission system supplying that region.

Appendix C: Northern Division 500 kV System Reinforcement Diagrams

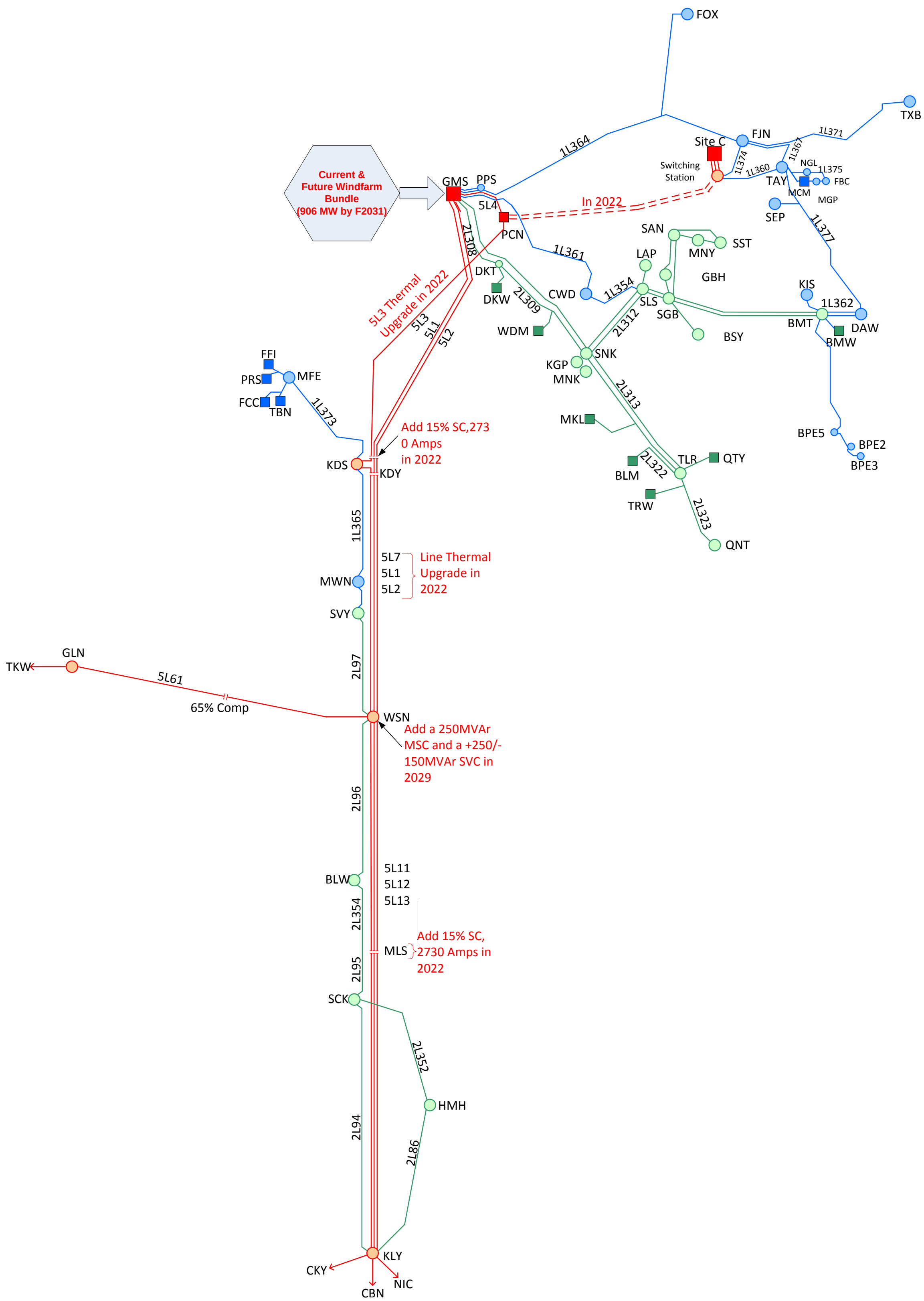

Figure C1, Alternative 1 Northern Division 500 kV Transmission Corridor Reinforcements (2022 & 2029 for BRP)

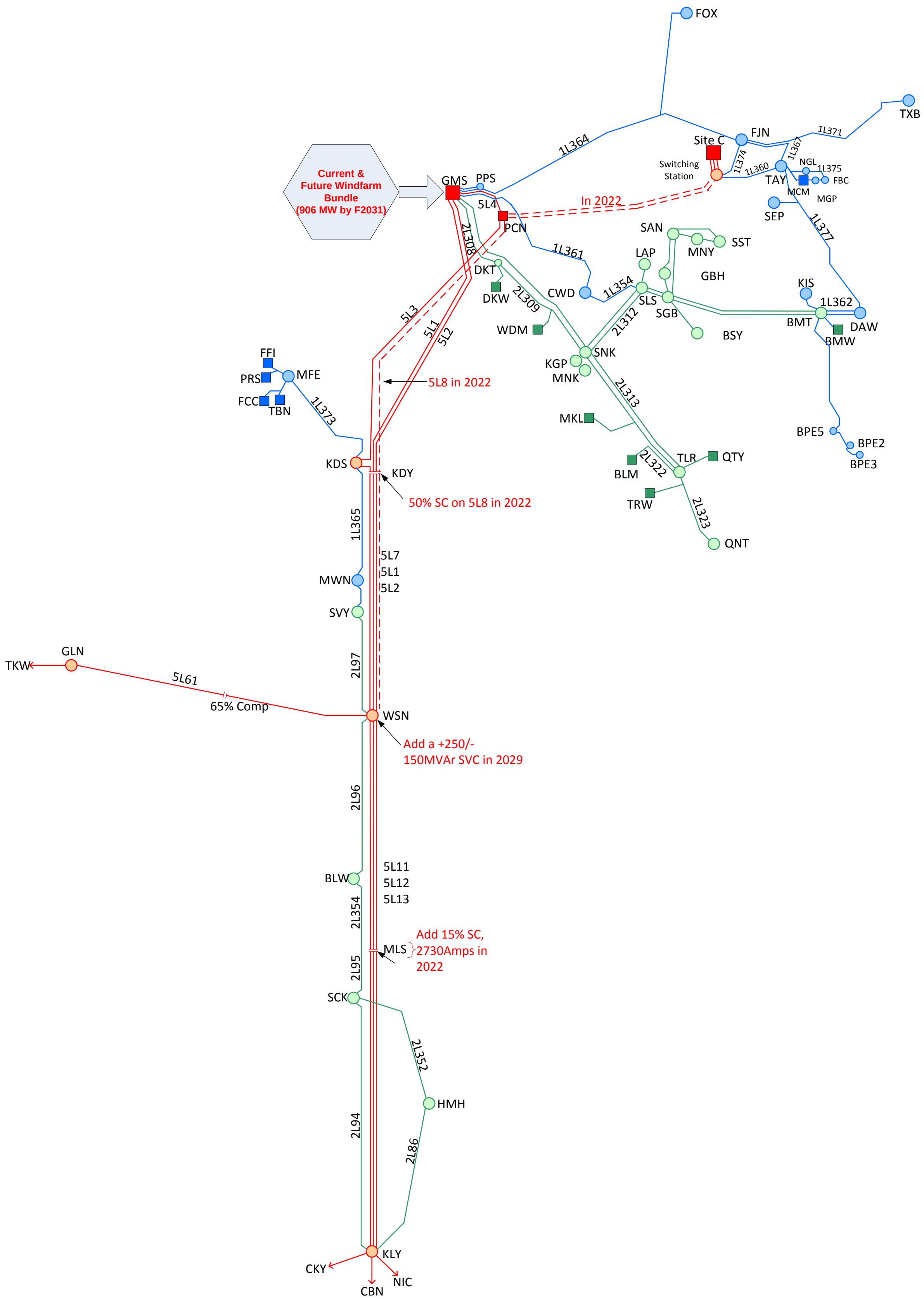

Figure C2, Alternative 2 Northern Division 500 kV Transmission Corridor Reinforcements (2022 & 2029 for BRP)

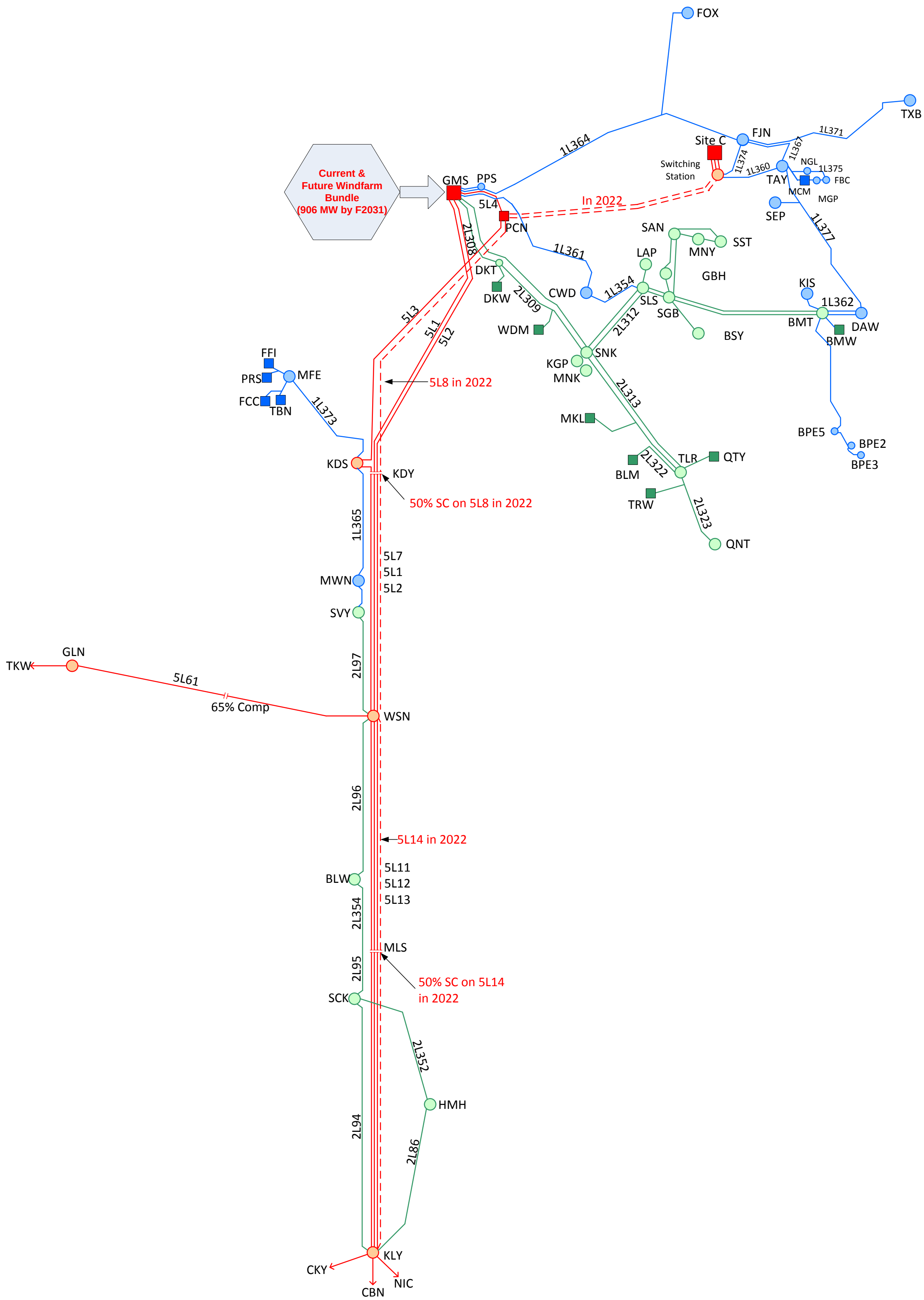

Figure C3, Alternative 3 Northern Division 500 kV Transmission Corridor Reinforcements (2022 for BRP)

Appendix D: Peace Region Transmission System Reinforcements

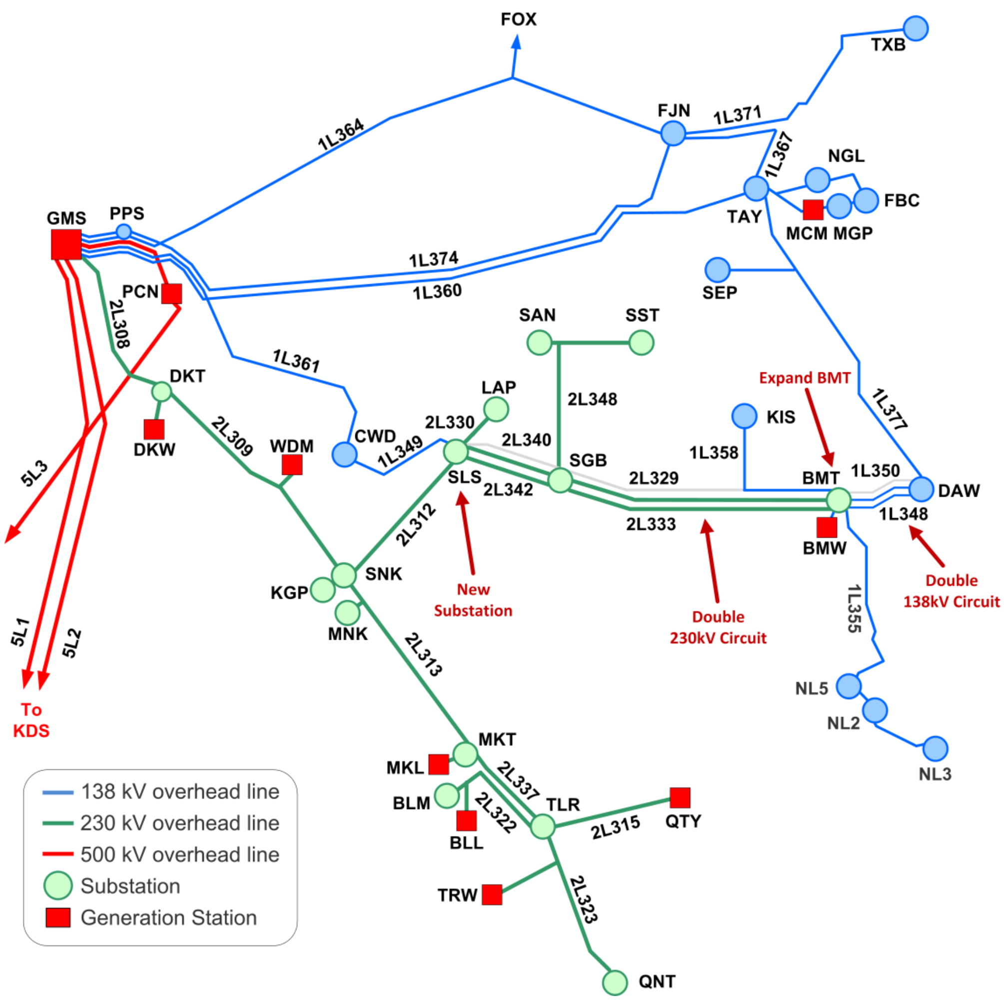

Figure D-1, DCAT Project Scope Diagram

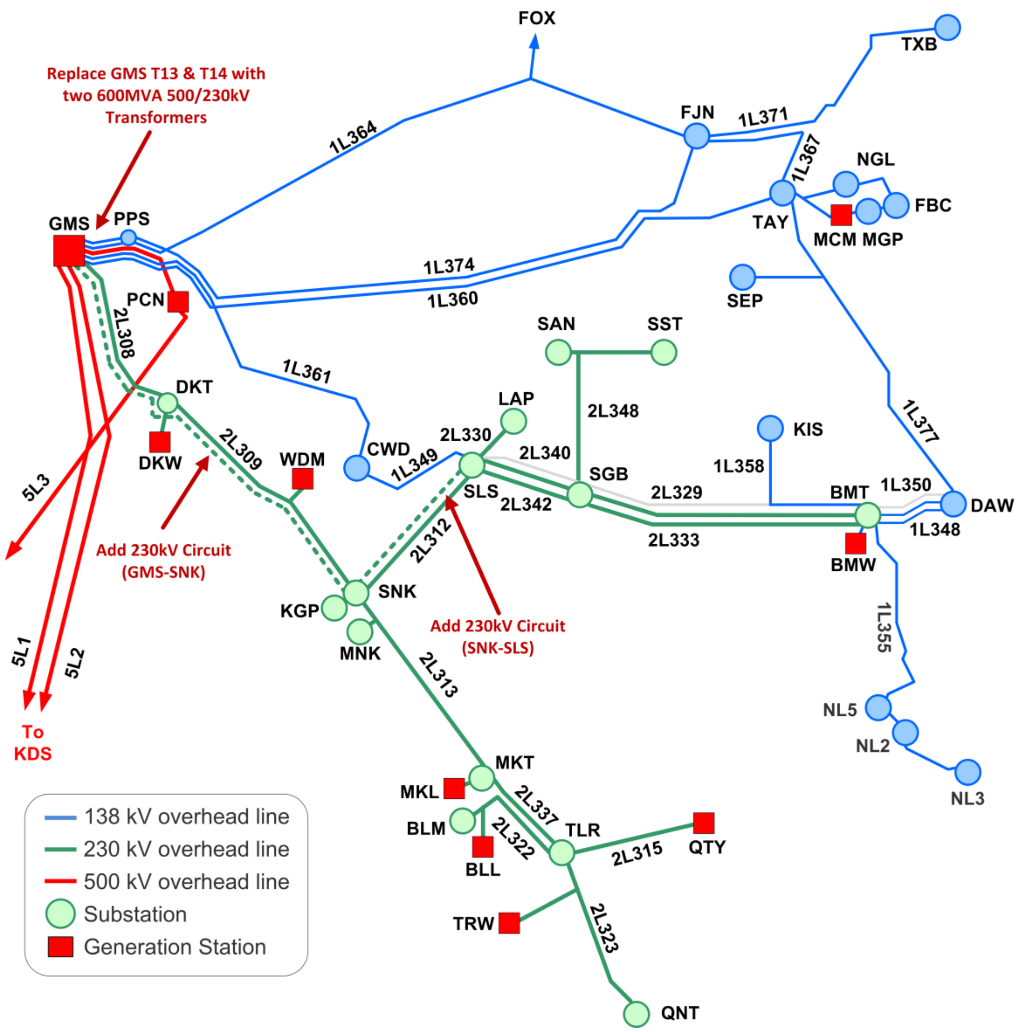

Figure D-2, PRES Alternative 1

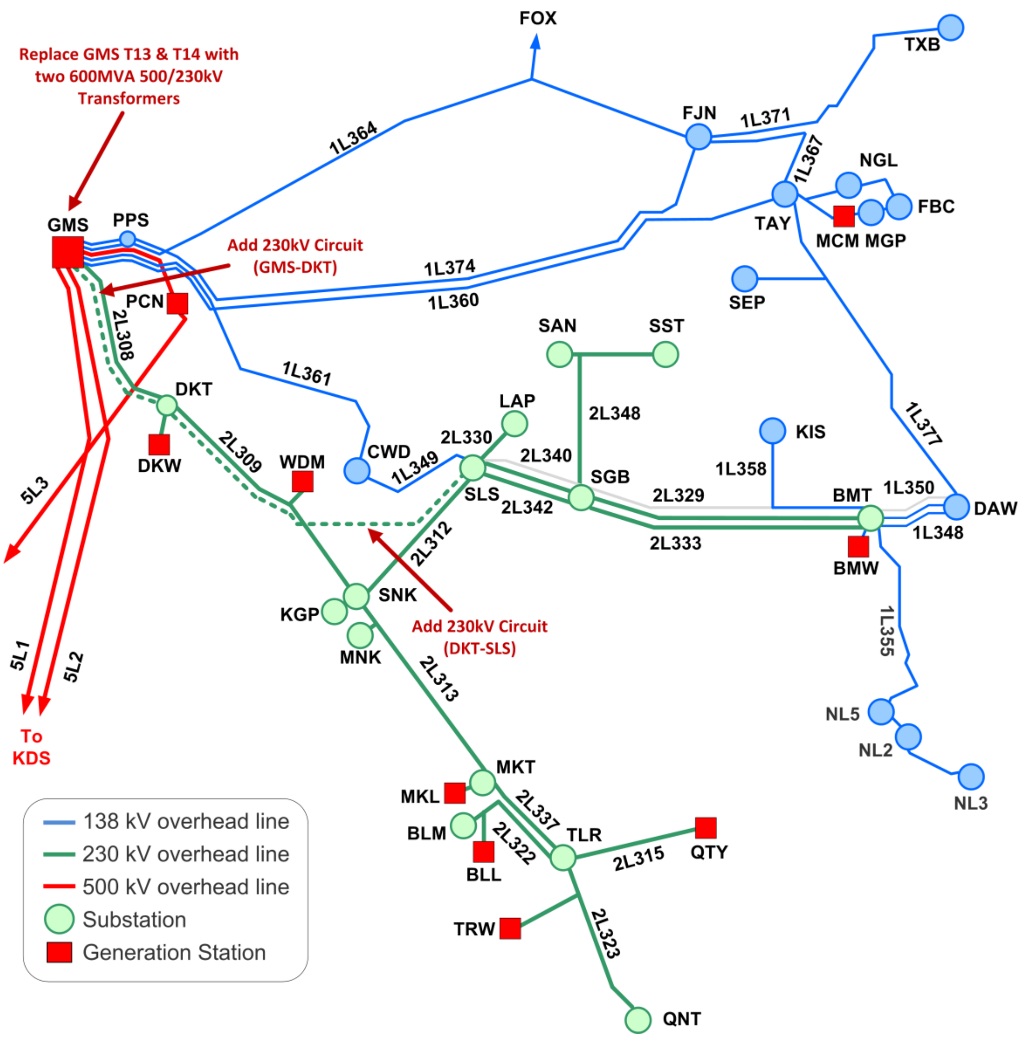

Figure D-3, PRES Alternative 2

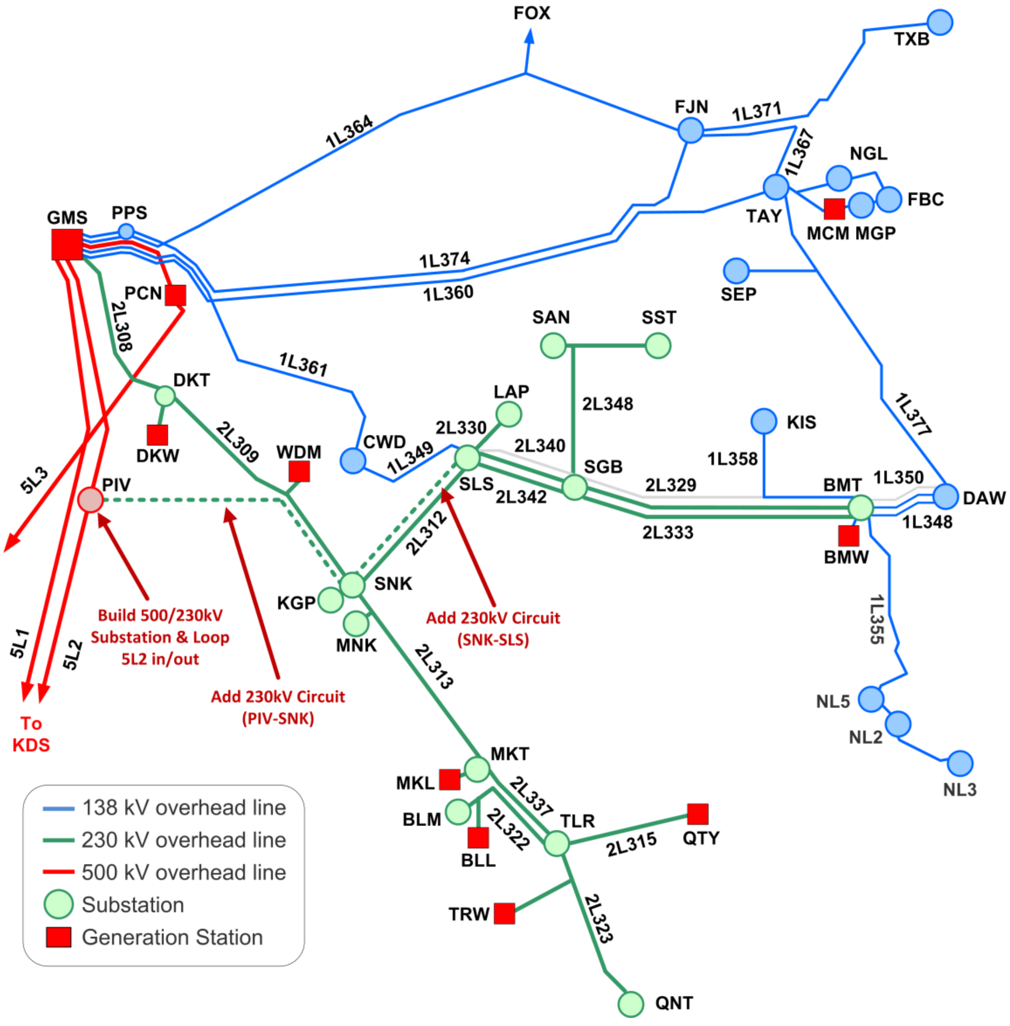

Figure D-4, PRES Alternative 3

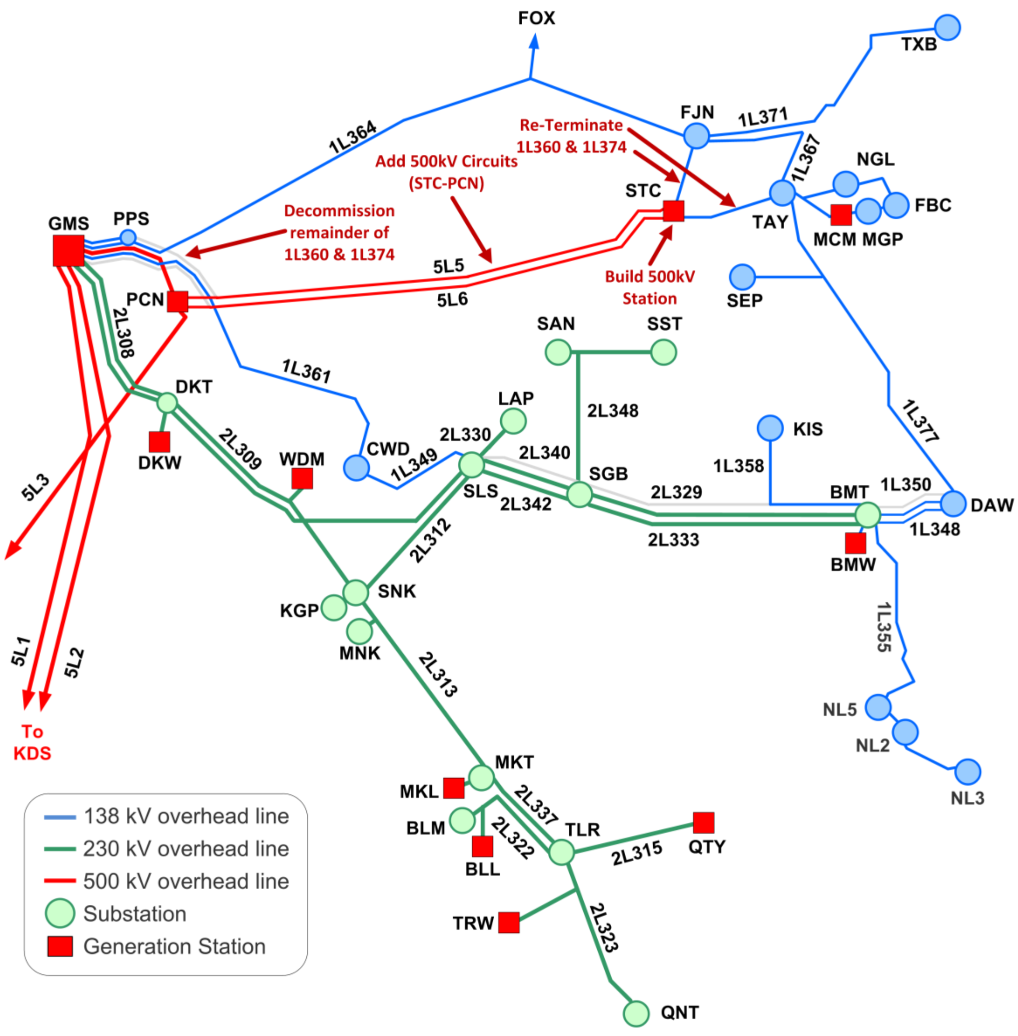

Figure D-5, Site C Clean Energy Project Interconnection Scheme Diagram

Appendix E: Metro Area Transmission System Reinforcements

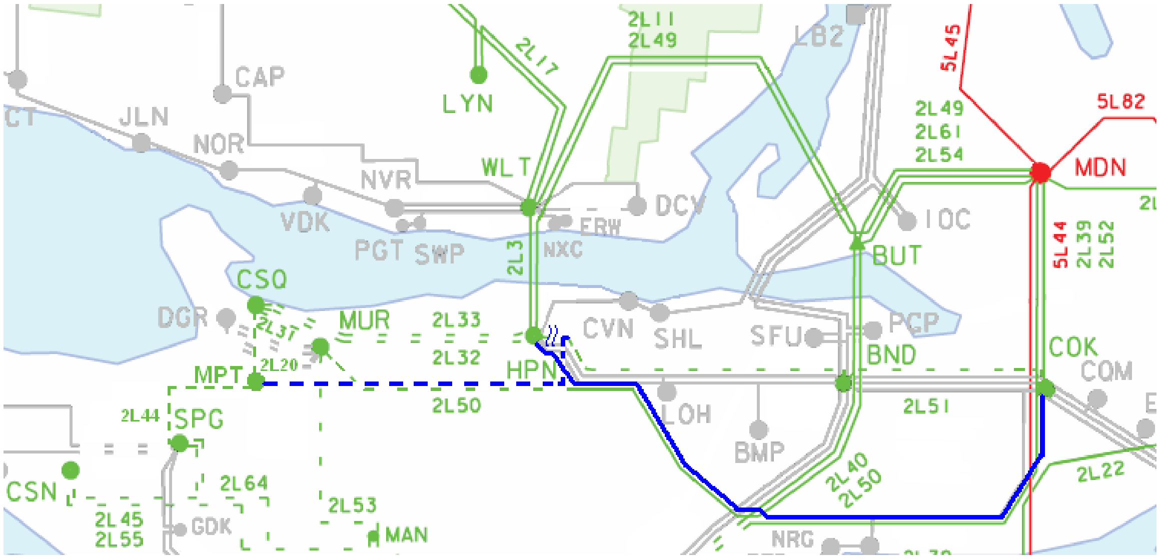

Figure E-1, Alternative 1: COK-HPN Transmission

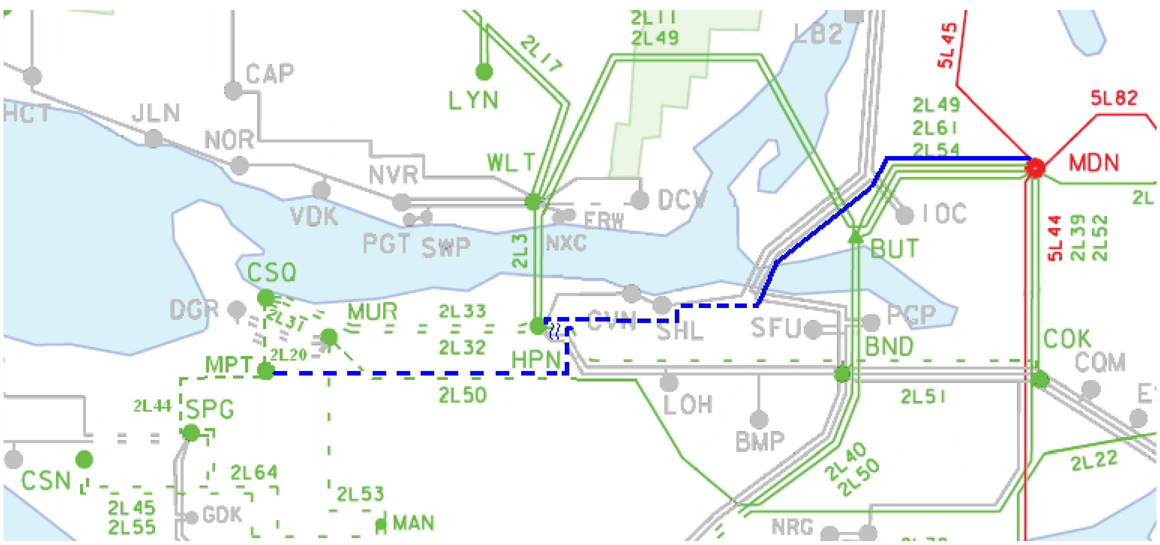

Figure E-2, Alternative 2: MDN-HPN Transmission near BUT

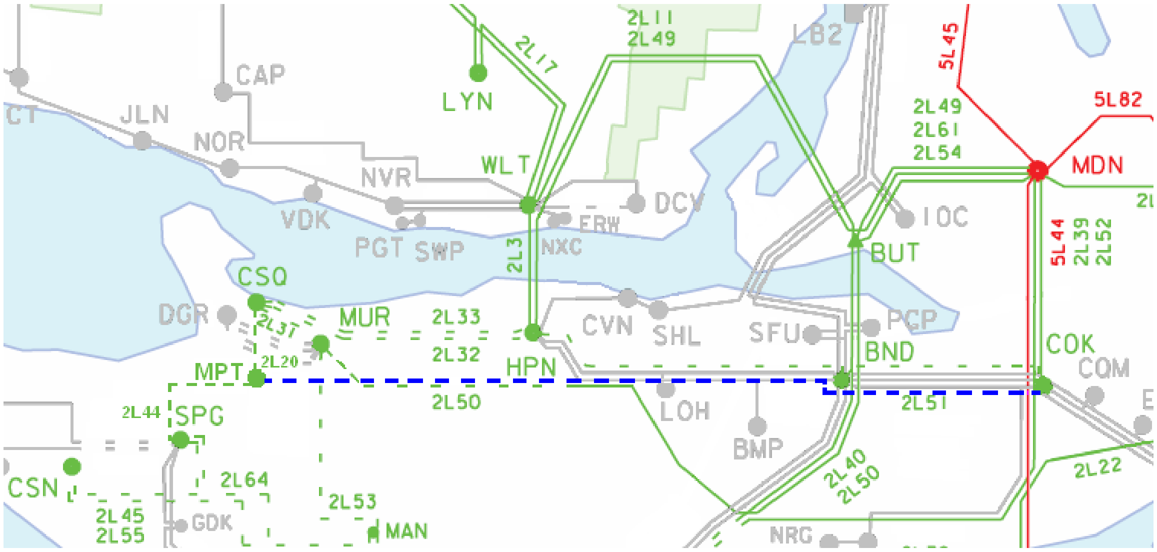

Figure E-3, Alternative3: COK-MPT Transmission

Appendix F: Major Transmission System Reinforcements from F2014 to F2033

Table F-1: Bulk Transmission System Reinforcements Projects F2014 ~ F2033

Division System	Transmission System Reinforcement Projects		Target ISD	Project Status	Project Drivers	Notes
North Division	Site C Clean Energy Generation Interconnection	1, Construct 500 kV Site C substation to accommodate the three 500 kV short circuits from Site C Powerhouse.	2022-10-01	Project Definition Phase	SGIP	
		2, Build double 500 kV circuits from Site C substation to PCN 500 kV Switchgear on the right-of-way of 1L374&1L360.				
		3, Terminate the two 500 kV circuits at PCN 500 kV switchgear.				
		4, Insall two 500/138 kV transformers at Site C substation and re-terminate 1L374&1L360 at Site C substation.				
	Northern Division 500kV Transmission Corridor Reinforcement	**Alternative 1 (refer to Figure C-1):**		Need Identification Phase	Generation Interconnections of Wind Power Bundles in South Peace area	
		1, Add 15% series compensation on 5L1, 5L2 and 5L3/7 at KDY substation with the nominal ratings of 2730 Amps	2022-10-01			
		2, Add 15% series compensation on 5L11, 5L12 and 5L13 at MLS substation with the nominal ratings of 2730 Amps				
		3, Thermal upgrades of 5L1/2/3/7 to 2700 Amps (summer)				
		4, Add 500 kV 250 MVAR of Mechanically Switched Shunt Capacitor at WSN	2029-10-01			
		5, Add +250/-150 MVAR of Satic Var Compensator (SVC) at WSN				
		Alternative 2(refer to Figure C-2):				
		1, Build new 500 kV transmission line 5L8 from PCN to WSN with 50% series compensation	2022-10-01			
		2, Add 15% series compensation on 5L11, 5L12 and 5L13 at MLS substation with the nominal ratings of 2730 Amps				
		3, Add +250/-150 MVAR of Satic Var Compensator (SVC) at WSN	2029-10-01			
		Alternative 3 (refer to Figure C-3):				
		1, Build new 500 kV transmission line 5L8 from PCN to WSN with 50% series compensation	2022-10-01			
		2, Build new 500 kV transmission line 5L14 from WSN to KLY with 50% series compensation				
North Coast	Prince George - Terrace Compensation (PGTC)	1, 65% series compensation on 5L61/5L62/5L63.	2019-04-01	Project Definition Phase	North Coast Transmission Voltage Load Growth	
		2, 230 kV Mechanically Switched Shunt Capacitor Banks at GLN: 2 x 130 MVAr + 1 x 30 MVAr	2019-04-01			
South Interior	Seymour Arm Series Capacitor Station (SASC)	Build series capacitor station at Seymour Arm with 50% series compensation on 5L71 and 5L72 and 3000 Amps of nominal ratings.	2014-10-01	Project Implementation Phase	Mica Unit 5 and Unit 6 Interconnection	
	Nicola 500kV Substation Reconfiguration	Reconfiguaring 500 kV bus-bar configuration: 1. bus-conductor replacement; 2) Line termination adjustment for 5L71, 5L76 and 5L81; and 3, 500 kV circuit breaker addition at transformer primary sides.	2014-10-01	Project Implementation Phase	500 kV bus overload and system reliability improvement	
	Nicola - Vaseux Lake Compensation (NVLC)	1, Adding 50% series compensation station on 5L98 at Trout Creek	2018-10-01	Need Identification Phase	Revelstoke Unit 6 Integration	
		2, Add one 500 kV mechenically switched shunt capacitor at NIC 500 kV buses. The size is 250 MVAR (or larger)				
Interior to Lower Mainland (ILM)	Interior to Lower Mainland Transmission Reinforcement Project (ILM)	1, Build 5L83 transmission line with 122.5 MVAr fixed shunt reactor at NIC substation	2015-01-31	Project Implementation Phase	1, Load growths at Laower Mainland and Vancouver Island	
		2, Add series capacitor station at Ruby Creek with 50% series compensation on 5L83			2, Burrard Generation Station de-designation	
	LM Pumped Storage Station Integration	**Option 1: POI @ 5L82 (or 5L83)**		Study Stage	SGIP	
		1, Loop 5L82 (or 5L83) into (i) new 500 kV switchgear at LM Pumped Storage station or (ii) new 500 kV switching station near 5L82/83.	2029-04-01			
		2, System Reinforcement between MDN and ING - build 5L43 from MDN to ING	2029-04-01			
		Option 2: POI @ CBN				
		Build double 500 kV lines from the new Pumped Storage station to CBN	2029-04-01			

Table F-2: Regional Transmission System Reinforcements Projects F2014 ~ F2033

Regional System	Transmission System Reinforcement Projects		Target ISD	Project Status	Project Drivers
Peace Region	Dawson-Chetwynd Area Transmission (DCAT) Project (Figure D-1)	1, Build a new 230/138 kV substation named Sundance Substation (SLS) with looping 2L312 into SLS	2015-06-01	Project Implementation Phase	Oil & Gas industrial load growth
		2, Construct two 230 kV transmission lines from SLS to Bear Mountain Terminal Substation (BMT)			
		3, Construct two new 230 kV transmission lines (operated at 138 kV) between BMT and Dawson Creek Substation (DAW).			
	Peace Region Electric Supply (PRES) Project	**Alternative 1 (refer to Figure D-2):**		Need Identification Phase	Oil & Gas industrial load growth
		1, Replace the existing two 500/230 kV 300 MVA transformers at GMS (GMS-T13 and GMS-T14) with two 500/230 kV 600 MVA transformers	2018-12-01		
		2, Construct a new 73 km long 230 kV overhead transmission circuit from GMS to SNK			
		3, Construct a new 30 km long 230 kV overhead transmission circuit from SNK to SLS			
		Alternative 2(refer to Figure D-3):			
		1, Replace the existing two 500/230 kV 300 MVA transformers at GMS (GMS-T13 and GMS-T14) with two 500/230 kV 600 MVA transformers	2018-12-01		
		2, Construct a 23 km long 230 kV overhead transmission circuit from GMS to DKT			
		3, Construct a 64 km long 230 kV overhead transmission circuit from DKT to SLS			
		Alternative 3 (refer to Figure D-4):			
		1, Construct a new 500/230 kV substation (PIV) near Pine Valley and loop 5L2 into the substation	2018-12-01		
		2, Construct a new 52 km long 230 kV overhead transmission circuit from PIV to SNK			
		3, Construct a new 30 km long 230 kV overhead transmission circuit from SNK to SLS			
	Peace Region System Reinforcement after Site C Interconnection	**Alternative 1:**		Study Stage	Site C Interconnection and Oil & Gas industrial load growth
		1, Open 1L377 under normal operation conditions to alleviate 1L377 overload	2022-10-01		
		2, Thermal upgrades (or line re-conductor) of 2L308 and 2L309	2025-10-01		
		3, Reactive Power Compensation (SVC sets) at SLS-SNK 239 kV system	2028-10-01		
		Alternative 2:			
		1, Add a Phase-Shifting Transformer on 1L377 at TAY	2022-10-01		
		2, Re-conductor 1L374 and 1L360 with heavy duty condictor	2025-10-01		
Metro Area	Metro Area Transmission Reinforcement	**Alternative 1:**		Need Identification Phase	Load Growth
		1, Construct a 230 kV transmission circuit from COK to HPN, and extend circuit 2L51 from HPN to MPT.	2018-10-01		
		2, Construct an overhead transmission circuit from MDN to COK and tie it to the extended circuit 2L51 (COK-MPT) inside COK yard.	2024-10-01		
		3, Add a fourth 500/230kV transformer at ING.	2028-10-01		
		4, Reconduct circuits 2L10 and 2L57 to heavy duty conductor circuits.			
		5, Construct an ARN-KI2 overhead transmission and install 700MVA 230kV +/-30˚ phase shifting transformer at ARN in series with this circuit.			
		6, Construct an ING-NEL transmission circuit.	2030-10-01		
		Alternative 2:			
		1, Construct a 230 kV transmission circuit from MDN to HPN passing near BUT, and extend circuit 2L51 from HPN to MPT.	2018-10-01		
		2, Add a fourth 500/230kV transformer at ING.	2028-10-01		
		3, Reconduct circuits 2L10 and 2L57 to heavy duty conductor circuits.			
		4, Construct an ARN-KI2 overhead transmission and install 700MVA 230kV +/-30˚ phase shifting transformer at ARN in series with this circuit.			
		5, Construct an ING-NEL transmission circuit.	2030-10-01		
		Alternative 3:			
		1, Construct a 230 kV underground transmission circuit from COK to MPT.	2018-10-01		
		2, Construct an overhead transmission circuit from MDN to COK and tie it to the existing circuit 2L51 (COK-HPN) inside COK yard.	2022-10-01		
		3, Add a fourth 500/230kV transformer at ING.	2026-10-01		
		4, Reconduct circuits 2L10 and 2L57 to heavy duty conductor circuits.			
		5, Construct an ARN-KI2 overhead transmission and install 700MVA 230kV +/-30˚ phase shifting transformer at ARN in series with this circuit.			
		6, Add 230kV 2.7ohm series reactor (i.e. x1=0.005pu) on the extended circuit 2L51 (MDN-HPN) at HPN.	2030-10-01		
		7, Construct an ING-NEL transmission circuit.			